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AND

JOURNAL

OF THE

Mineralogical Society.

INSTITUTED 3rd FEBRUARY, 1876.

EDITED BY L. J. SPENCER, M.A.,

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THE MINERALOGICAL SOCIETY

MINERALOGICAL SOCIETY.

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MINERALOGICAL SOCIETY

(*Instituted 3rd February, 1876*).

BYE-LAWS.[1]

1. The object of the Mineralogical Society of Great Britain and Ireland, with which the Crystallological Society was amalgamated on 11th December, 1888, shall be to advance the knowledge of Mineralogy, and also of Crystallography and Petrology.

2. The Society shall consist of Ordinary Members and Honorary Members.

Ordinary Members.

3. Every candidate for Ordinary Membership shall be proposed by two Ordinary Members, one, at least, of whom shall have personal knowledge of the candidate.

4. The names of the Candidates shall be communicated to every Ordinary Member by the General Secretary.

5. Elections to Ordinary Membership shall be made by the Council at a meeting held at least four weeks after the names of the Candidates have been so communicated; and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the members present and voting.

6. Ordinary Members shall pay an Entrance Fee of one guinea and an annual subscription of one guinea. Ordinary Members elected on or before November 13th, 1900, shall be entitled to compound for the annual subscription by a single payment of ten guineas: Ordinary Members elected after that date shall be entitled to compound by a single payment of fifteen guineas.

7. Annual Subscriptions shall be due on the first of January of each year, but Members elected after the first of October shall not be required to pay a subscription for the then current year.

[1] Adopted at the Anniversary Meeting, November 13th, 1900.

8. The name of any Ordinary Member whose subscription is more than two years in arrear shall be brought before the Council, and an intimation that this action has been taken shall be communicated to the Member. After the expiration of at least one year from that date, the Council shall be empowered to erase the name from the List of Members.

Honorary Members.

9. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither Entrance Fee nor Annual Subscription.

10. Every candidate for Honorary Membership shall be proposed by two Members of the Council, and the election shall be by the Council.

11. The names of all candidates proposed for Honorary Membership shall be communicated by the General Secretary to every Member of the Council, and the election shall not take place until the expiration of four weeks after such communication.

Council.

12. The Society shall be governed by a Council, consisting of a President, two Vice-Presidents, a General Secretary, a Foreign Secretary, a Treasurer, an Editor of the Journal, and twelve Ordinary Members.

13. All members of the Society who have served the office of President shall be life-members of the Council.

14. The Council shall be elected annually at the Anniversary Meeting.

15. Four Ordinary Members of Council shall retire annually, and shall not be eligible for re-election until the next Anniversary Meeting.

16. The Council shall prepare a List of Members nominated for election as Officers and Ordinary Members of Council.

17. The election of Council shall be effected by the agency of voting papers containing the List nominated by the Council. They shall be sent by the General Secretary, at least four weeks before the Anniversary Meeting, to every Ordinary Member of the Society, and every such Member shall be entitled to substitute the names of any other Ordinary Members of the Society for those on the List.

18. The voting papers shall be returned by the Members to the General Secretary, and shall be examined at the Anniversary Meeting by two Scrutineers appointed by the Chairman, who shall on their report declare the result of the election. The voting papers need not be signed.

19. The Council shall have power to appoint Officers, and to co-opt Ordinary Members of Council, to fill vacancies in the Council caused by death or resignation during the interval between two Anniversary Meetings.

20. Meetings of the Council shall be summoned by order of the President or the Council; at such meetings three shall be a quorum, of whom one shall be either the President, a Vice-President, the Treasurer or the General Secretary.

21. A Report of Council on the work and progress of the Society shall be submitted at each Anniversary Meeting.

Trustees.

22. Two or more Trustees shall be appointed by the Council, and the invested property of the Society shall stand in their names.

23. Composition-fees shall be treated as Capital: a Resolution of the Society at a general meeting, summoned with notice of a proposed disposition of property, shall be sufficient authority to the Trustees to give effect to such disposition; provided that a resolution of the Council shall be sufficient authority for any change of investment.

Meetings.

24. Meetings of the Society shall be summoned from time to time, as may be deemed necessary by the Council, or at the requisition of any ten Members of the Society. One of these meetings in each year shall be termed the Anniversary Meeting.

Journal.

25. The Numbers of the *Mineralogical Magazine and Journal of the Society* shall be issued at such intervals as the Council shall determine, and shall be sent, postage paid, to every Member of the Society.

Auditors and Balance Sheet.

26. Two Ordinary Members of the Society, one of whom is not a Member of the Council, shall be appointed annually by the Council to audit the accounts of the Society.

27. No auditor shall serve for more than three years in succession.

28. The audited Balance-Sheet, after submission to the Council, shall be published in the Journal of the Society as early as possible in every year.

Expulsion of Members.

29. A majority consisting of three-fourths of the whole Council shall have power to expel a Member from the Society, but a Member who has been expelled shall have a right of appeal to the Society. Notice of such appeal to the Society shall be sent by such Member to the General Secretary within four weeks of the expulsion, and the appeal shall be considered by the Society at the next Anniversary Meeting; a majority of the votes recorded at such Meeting sufficing to confirm or annul the decision of the Council.

Alteration of the Bye-Laws.

30. The Bye-laws may be altered only at an Anniversary Meeting, and only by a majority consisting of three-fourths of the Members present and voting. Notice of changes proposed to be made in the Bye-laws shall be communicated by the General Secretary to every Ordinary Member of the Society at least four weeks before the Anniversary Meeting at which they are to be considered.

Obligation Book.

31. Ordinary Members, by payment of their Entrance Fee, signify their acceptance of any Bye-laws approved by the Society; and every Member of the Society shall sign an Obligation Book.

LIST OF MEMBERS

(March 20th, 1901).

HONORARY MEMBERS.

M. E. Bertrand, *Paris.*
Dr. A. Brezina, *Vienna.*
Prof. W. C. Brögger, *Christiania.*
Prof. G. J. Brush, *New Haven, U.S.A.*
Prof. E. S. Dana, *New Haven, U.S.A.*
Prof. F. Fouqué, *Paris.*
Prof. P. Groth, *Munich.*
Prof. C. Klein, *Berlin.*
Prof. A. Lacroix, *Paris.*
Prof. V. von Lang, *Vienna.*
M. A. Michel Lévy, *Paris.*
Prof. E. Ludwig, *Vienna.*
M. V. L. Moissenet, *Chaumont.*
Baron A. E. Nordenskiöld, *Stockholm.*
Prof. A. Renard, *Gand.*
Prof. H. Rosenbusch, *Heidelberg.*
Dr. K. J. V. Steenstrup, *Copenhagen.*
Prof. G. Tschermak, *Vienna.*
Prof. F. J. Wiik, *Helsingfors.*
Prof. F. Zirkel, *Leipzig.*

ORDINARY MEMBERS.[1]

A. Annual Subscribers.

L. Life-Members.

C. Belonged to the Crystallological Society at the time of the amalgamation of the two Societies, December 11th, 1883.

	Date of Election.	
A	Nov. 11, 1890	Adcock, Samuel Robert, Esq. F.C.S. *16 Halseley Road, St. Helens, Lancashire.*
L	May 8, 1888	Arnold-Bemrose, Henry Howe, Esq. M.A. F.G.S. *56 Friar Gate, Derby.*
A	Dec. 14, 1881	Baker, Harry, Esq. F.C.S. *Epworth House, Maughland Lane, Runcorn, Cheshire.*
L	Nov. 20, 1894	Barlow, William, Esq. F.G.S. F.C.S. *The Red House, Stanmore, Middlesex.*
L	Feb. 3, 1876	Barnett, A. K., Esq. F.G.S. *11 Penrose Terrace, Penzance, Cornwall.*
L	Jan. 17, 1893	Barrow, George, Esq. F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
L	Feb. 2, 1897	Beale, William Phipson, Esq. K.C. F.G.S. F.C.S. *25 Sheffield Terrace, Kensington, London, W.*
A	Feb. 6, 1894	Beringer, John J., Esq. A.R.S.M. F.C.S. *School of Mines, Camborne, Cornwall.*
A	Nov. 20, 1894	Berkeley, The Rt. Hon. the Earl of, F.G.S. F.C.S. *Foxcombe, Boar's Hill, near Abingdon, Berks.*
L	Feb. 3, 1876	Bonney, The Rev. Prof. Thomas George, D.Sc. LL.D. F.R.S. *23 Denning Road, Hampstead, London, N.W.*
L	April 6, 1897	Bowman, Herbert Lister, Esq. M.A. F.C.S. *Mineral Department, The Museum, Oxford.*

[1] Corrections for this List should be sent to the General Secretary, 36 Woodville Road, Ealing, London, W.

	Date of Election.	
L	Dec. 18, 1876	Brown, Prof. Alexander Crum, M.D. D.Sc. F.R.S. *8 Belgrave Terrace, Edinburgh.*
L	June 25, 1885	Butler, Francis Henry, Esq. M.A. A.R.S.M. *158 Brompton Road, London, S.W.*
A	May 7, 1889	Butler, William Waters, Esq. F.C.S. *Southfield, Norfolk Road, Edgbaston, Birmingham.*
A	April 4, 1887	Chester, Albert Huntington, Esq. E.M. Ph.D. Sc.D. Professor of Mineralogy. *Rutgers College, New Brunswick, New Jersey, U.S.A.*
A	Feb. 3, 1876	Church, Professor Arthur Herbert, M.A. F.R.S. *Shelsley, Ennerdale Road, Kew, Surrey.*
A	May 8, 1888	Cole, Grenville A. J., Esq. M.R.I.A. F.G.S. Professor of Geology. *Royal College of Science, Dublin.*
L	April 12, 1892	Collins, Henry F., Esq. A.R.S.M. *14 Broad Street Avenue, London, E.C.*
L	Feb. 3, 1876	Collins, Joseph Henry, Esq. F.G.S. *14 Broad Street Avenue, London, E.C.*
L	April 3, 1900	Coomára-Swámy, Ananda K., Esq. B.Sc. F.L.S. F.G.S. *Walden, Worplesdon, near Guildford, Surrey.*
L	May 8, 1888	Crookes, Sir William, F.R.S. *7 Kensington Park Gardens, London, W.*
A	Jan. 31, 1899	Cullis, Charles Gilbert, Esq, D.Sc. F.G.S. Assistant-Professor in Mineralogy. *Royal College of Science, South Kensington, S.W.*
L	Jan. 31, 1899	Currie, James, Esq. M.A. F.R.S.E. *Larkfield, Golden Acre, Edinburgh.*
L	Feb. 3, 1876	Danby, Thomas William, Esq. M.A. F.G.S. *The Crouch, Seaford, Sussex.*
L	Oct. 20, 1885	Daw, John, Esq. Junr. *Brooklands, Rosemont Road, Acton, London, W.*
L	Nov. 15, 1898	De Castro, J. Paul, Esq. M.A. F.C.S. A.I.C. *School of Mines, Redruth, Cornwall.*
A	Nov. 15, 1898	Dickson, Hamilton Charles, Esq.
L	April 14, 1891	Evans, John William, Esq. LL.B. D.Sc. F.G.S. *Care of R. C. T. Evans, Esq. 9 Heathcote Street, London, W.C.*
L	Nov. 13, 1900	Fleischmann, Friedrich Noel Ashcroft, Esq. F.C.S, *6 Collingham Gardens, London, S.W.*

	Date of Election.	
L	C	Fletcher, Lazarus, Esq. M.A. F.R.S. Keeper of Minerals in the British Museum (Natural History), Cromwell Road, London, S.W. *36 Woodville Road, Ealing, London, W.*
L	Nov. 19, 1895	Fletcher, The Rev. Mark, M.A. F.G.S. Demonstrator in Mineralogy in the Durham College of Science. *Cramlington, R.S.O., Northumberland.*
L	Feb. 8, 1876	Foster, Clement Le Neve, Esq. D.Sc. B.A. F.R.S. H.M. Inspector of Metalliferous Mines for North Wales, etc. and Professor of Mining in the Royal College of Science, South Kensington, London, S.W. *Llandudno, North Wales.*
A	Feb. 8, 1876	Geikie, Sir Archibald, D.Sc. D.C.L. LL.D. F.R.S. Formerly Director-General of the Geological Surveys of the United Kingdom. *The Museum, 28 Jermyn Street, London, S.W.*
A	Feb. 8, 1876	Geikie, James, Esq. LL.D. D.C.L. F.R.S. Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*
L	Feb. 15, 1881	Gibb, T. J., Esq. *37 Old Jewry, London, E.C.*
L	May 10, 1886	Goldschmidt, Dr. Victor, Professor of Mineralogy in the University of Heidelberg. *9 Gaisbergstrasse, Heidelberg, Germany.*
A	April 2, 1895	Gordon, The Rev. John More, F.G.S. *St. John's Vicarage, Redhill, Surrey.*
L	April 12, 1892	Gregory, John Walter, Esq. D.Sc. F.G.S. Professor of Geology. *The University, Melbourne, Victoria, Australia.*
A	C	Gurney, The Rev. Henry Palin, D.C.L. M.A. F.G.S. Principal of the Durham College of Science, Newcastle-on-Tyne. *Roseworth, Gosforth, Newcastle-on-Tyne.*
A	Jan. 23, 1900	Hall, Arthur Lewis, Esq. B.A. F.G.S. *Dulwich College, Dulwich.*
A	Mar. 10, 1885	Harker, Alfred, Esq. M.A. F.G.S. Fellow of St. John's College, Cambridge: Geological Survey of Scotland. *St. John's College, Cambridge.*
A	Feb. 1, 1898	Hartley, Ernald George Justinian, Esq. B.A. F.C.S. *Apedale Hall, Newcastle-under-Lyme, Staffordshire.*

	Date of Election.	
L	Jan. 23, 1900	Hartley, Harold Brewer, Esq. B.A. F.C.S. *Balliol College, Oxford.*
A	June 3, 1879	Henson, Samuel, Esq. *97 Regent Street, London, W.*
A	May 8, 1888	Hoffmann, G. Christian, Esq. LL.D. Geological Survey of Canada. *Sussex Street, Ottawa, Canada.*
L	Nov. 17, 1896	Holland, Thomas H., Esq. A.R.C.S. F.G.S. *Geological Survey Office, Calcutta, India.*
A	Jan. 7, 1879	Horne, John, Esq. F.R.S. Geological Survey of Scotland. *Geological Survey Office, Sheriff's Court Buildings, Edinburgh.*
A	Feb. 3, 1876	Hudleston, Wilfrid Hudleston, Esq. M.A. F.R.S. *8 Stanhope Gardens, South Kensington, London, S.W.*
A	April 14, 1878	Hughes, Thomas M'Kenny, Esq. M.A. F.R.S. Professor of Geology in the University of Cambridge. *18 Hills Road, Cambridge.*
A	April 18, 1893	Hussak, Dr. Eugen. *Commissão Geographica e Geologica de S. Paulo, S. Paulo, Brâzil.*
L	Jan. 14, 1890	Hutchinson, Arthur, Esq. M.A. Ph.D. F.C.S. Demonstrator of Mineralogy in the University of Cambridge. *Pembroke College, Cambridge.*
A	Nov. 14, 1899	Jackson, Henry, Esq. B.A. B.Sc. F.C.S. *Downing College, Cambridge.*
L	April 3, 1884	Judd, John Wesley, Esq. C.B. LL.D. F.R.S. Professor of Geology in, and Dean of, the Royal College of Science, South Kensington, S.W. *16 Cumberland Road, Kew, Surrey.*
L	Feb. 3, 1876	Kinch, Edward, Esq. F.C.S. Professor of Chemistry. *Royal Agricultural College, Cirencester.*
L	Feb. 3, 1876	Kitto, Benedict, Esq. F.I.C. F.G.S. *26 Lancaster Road, Finsbury Park, London, N.*
A	Oct. 20, 1885	Kunz, George Frederick, Esq. M.A. *Care of Messrs. Tiffany & Co., Union Square, New York City, U.S.A.*
A	C	Lewis, William James, Esq. M.A. F.C.S. Professor of Mineralogy in the University of Cambridge. *The New Museums, Cambridge.*
A	May 10, 1886	Lindsey, C. R., Esq. B.Sc. *509 Edge Lane, Droylesden, Manchester.*

	Date of Election.	
L	C	Liveing, George Downing, Esq. M.A. F.R.S. Professor of Chemistry in the University of Cambridge. *Newnham, Cambridge.*
L	Sept. 6, 1876	Liversidge, Archibald, Esq. M.A. LL.D. F.R.S. Professor of Chemistry. *The University, Sydney, New South Wales.*
A	Oct. 21, 1879	Louis, Henry, Esq. M.A. A.R.S.M. F.G.S. Professor of Mining. *Durham College of Science, Newcastle-on-Tyne.*
L	Sept. 2, 1881	Mallet, Frederick Richard, Esq. F.G.S. F.C.S. *18 The Common, Ealing, London, W.*
L	Dec. 12, 1882	McMahon, Lieut.-General Charles Alexander, F.R.S. *20 Nevern Square, South Kensington, London, S.W.*
L	Feb. 3, 1876	Merry, J. S., Esq. *Swansea, South Wales.*
L	C	Miers, Henry Alexander, Esq. M.A. D.Sc. F.R.S. Professor of Mineralogy in the University of Oxford. *Magdalen College, Oxford.*
A	Feb. 19, 1878	Milne, Prof. John, F.R.S. *Shide Hill House, Shide, Newport, Isle of Wight.*
A	May 10, 1886	Moberg, Dr. Bergrath K. Ad. *Helsingfors, Finland.*
L	Feb. 3, 1876	Morris, James, Esq. *6 Windsor Street, Swansea, South Wales.*
A	C	Müller, Hugo, Esq. Ph.D. F.R.S. *13 Park Square East, Regent's Park, London, N.W.*
L	April 5, 1880	Pearce, Richard, Esq. F.G.S. *Denver City, Colorado, U.S.A.*
A	Feb. 15, 1881	Platnauer, Henry Maurice, Esq. B.Sc. A.R.S.M. F.G.S. *The Museum, York.*
L	June 20, 1899	Pollard, William, Esq. M.A. Ph.D. F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
A	Nov. 10, 1891	Pope, William Jackson, Esq. F.C.S. *Goldsmiths' Institute, New Cross, London, S.E.*
A	Jan. 11, 1887	Pringle, A., Esq. M.A. B.Sc. Assistant Curator, Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
L	Jan. 11, 1887	Prior, George Thurland, Esq. M.A. F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

	Date of Election.	
A	Nov. 11, 1890	Rich, W. Esq. *Trevu, Camborne, Cornwall.*
A	Feb. 3, 1876	Rudler, Frederick William, Esq. F.G.S. Curator of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
A	May 8, 1888	Rutley, Frank, Esq. F.G.S. *59 Perham Road, West Kensington, London, W.*
L	Feb. 3, 1876	Scott, Robert Henry, Esq. M.A. D.Sc. F.R.S. *6 Elm Park Gardens, London, S.W.*
A	July 3, 1884	Seligmann, Gustav, Esq. *18 Schlossrondel, Coblentz, Rhenish Prussia.*
A	June 25, 1889	Siggers, J. G., Esq. *13 Gothic Arcade, Snow Hill, Birmingham.*
L	April 6, 1897	Smith, George Frederick Herbert, Esq. M.A. F.R.A.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	June 17, 1897	Sollas, William Johnson, Esq. D.Sc. LL.D. F.R.S. Professor of Geology in the University of Oxford. *The Museum, Oxford.*
A	C	Solly, Richard Harrison, Esq. M.A. F.G.S. *2 Wollaston Road, Cambridge.*
L	Feb. 3, 1876	Sorby, Henry Clifton, Esq. LL.D. F.R.S. *Broomfield, Sheffield.*
A	Feb. 6, 1894	Spencer, Leonard James, Esq. M.A. F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	Feb. 19, 1878	Spezia, Sig. Giorgio, Professor of Mineralogy. *The University, Turin, Italy.*
A	C	Story-Maskelyne, Prof. Mervin Herbert Nevil, M.A. F.R.S. *Basset Down House, Swindon, Wilts.*
A	Nov. 16, 1897	Strutt, The Hon. Robert John, B.A. *Trinity College, Cambridge.*
A	July 18, 1883	Teall, J. J. Harris, Esq. M.A. F.R.S. Director of the Geological Survey of the United Kingdom and of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
L	Feb. 15, 1881	Terrill, William, Esq. F.C.S. *42 St. George's Street, Swansea, South Wales.*
L	Aug. 15, 1877	Trechmann, Charles O., Esq. J.P. Ph.D. F.G.S. *Hudworth Tower, Castle Eden, Co. Durham.*
A	April 14, 1891	Tutton, Alfred Edwin, Esq. B.Sc. A.R.C.S. F.R.S. *17 Bardwell Road, Oxford.*

	Date of Election.	
A	Feb. 3, 1876	Walker, John Francis, Esq. M.A. F.G.S. F.L.S. F.C.S. *45 Bootham, York.*
L	Feb. 6, 1894	Watts, William Whitehead, Esq. M.A. F.G.S. Assistant Professor of Geology, University of Birmingham. *Holmwood, Bracebridge Road, Four Oaks, Sutton Coldfield, Warwickshire.*
L	Nov. 19, 1895	Webb, R. C., Esq. *Kimberley Club, Kimberley South Africa.*
L	Mar. 19, 1901	Weston, Digby St. A. P., Esq. Lieutenant R.N., H.M.S. "Diana," Mediterranean Squadron. *Greenfields, East Sheen, London, S.W.*
L	Feb. 3, 1876	Wills, J. Lainson, Esq. F.C.S. *Care of Dr. F. Wyatt, 39 South William Street, New York City, U.S.A.*
L	June 23, 1896	Wills, Louis, Esq. *29 Cornhill, London, E.C.*
L	June 3, 1882	Wiltshire, The Rev. Thomas, M.A. D.Sc. F.G.S. F.L.S. F.R.A.S. Professor Emeritus, King's College, London. *25 Granville Park, Lewisham, London, S.E.*
A	Feb. 18, 1889	Woodward, Bernard Henry, Esq. F.G.S. *The Museum, Perth, Western Australia.*
L	C	Woodward, Charles J., Esq. B.Sc. F.G.S. Birmingham Municipal Technical School. *97 Harborne Road, Birmingham.*
A	June 17, 1897	Woollett, N. E., Esq. *Wingham, Dover, Kent.*

LIST OF SERIALS IN THE LIBRARY.

(March, 1901).

Librarian: Prof. W. J. Lewis, The New Museums, Cambridge.

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Bristol Naturalists' Society, Proceedings	From Vol. III, 1880 to VI, 1891	—
Cornwall, Royal Institution, Journal	IX, 1886 to XIII (4), 1898	Part 37, 1891; Part 39, 1893
Edinburgh Geological Society, Transactions	VII, 1894–9	—
Glasgow Geological Society, Transactions	X, 1892–6	—
Mineralogical Magazine (2 copies), I, 1876 to XII, 1900	—	—
Naturalist, The	1885 to 1899	Nos. 139, 142, 1887
North of England Institute of Mining and Mechanical Engineers	XXVI, 1876 to XLIX, 1900	—
Yorkshire Naturalists' Union, Transactions	I, 1878 to XXI, 1898	IX to XIX
Australian Museum (Sydney), Records	I, 9, 1891 to III, 7, 1900	—
Australian Museum (Sydney), Reports	1882 to 1899	—
New South Wales, Royal Society, Journal and Proceedings	IX, 1875 to XXXIII, 1899	XIII, 1879; XIV, 1883; XVII, 1887
New South Wales, Department of Mines, Annual Reports	1876 to 1899	1878, 9; 1882, 3; 1885; 1887–9; 1897
New South Wales, Mines and Mineral Statistics	1875 to 1880	—
New South Wales, Geological Survey, Records	II, 1890 to VI, 1900	—
New South Wales, Geological Survey, Memoirs	Nos. 1 to 9	No. 6
New South Wales, Technological Museum, Reports	1883 to 1890	1887
Victoria, Mineral Statistics	1876 to 1881	—
Victoria, Reports of Chief Inspector of Mines	1874, 5; 1881	—
Victoria, Reports of Mining Surveyors	March 1875 to Sept. 1882	—
New Zealand, Geological Survey, Reports, 1874 to 1878	—	—
Canada, Geological Survey, Reports, 1894 to 1897	1879 to 1893	—

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Nova Scotian Institute Nat. Sci., Proceedings and Transactions	IV, 4, 1877 to X, 1, 1899	V, 2 and 4; VI; VII, 1, 2
American Chemical Journal, II, 1880 to XXII, 1899	I, 1879	—
American Geologist, XVII, 1896 to XXVI, 1900	—	—
American Journal of Science, XIII [iii] 1877 to X [iv], 1900	—	—
Journal of Geology, V, 1897 to VIII, 1900	—	—
California, Annual Reports of the State Mineralogist	IV, 1884 to XIII, 1896	—
Colorado Scientific Society, Proceedings	I, 1883 to III, 1889	II, 1; III, 1
New York Academy of Sciences, Annals	1881–3	—
New York Academy of Sciences, Transactions	1881–3	—
Philadelphia Academy of Natural Sciences, Proceedings, 1877 to 1884	—	1881; 1883
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PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 22nd, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Secretary reported that the nomination of Lieutenant D. St. A. P. Weston, R.N., for the Membership of the Society had been communicated to the Members.

The resignation of Mr. Boulger and the death of Mr. Taylor, Ordinary Members, were announced.

The President, the General Secretary, the Editor of the Journal, Dr. Hugo Müller and Professor Miers were appointed to serve on the Editorial Committee of the Journal.

Messrs. Collins and Kitto were elected auditors for the accounts of the Society for the years 1900 and 1901.

The audited Balance Sheet for the year ending December 31st, 1900, was submitted and approved.

Resolved to issue a List of Members and the Bye-Laws as part of each volume of the Journal.

The President generously offered to present certain volumes of the Bulletin of the French Mineralogical Society; and also to present the sum of ten pounds to the Society for use in the binding of the books in the Library: a vote of thanks was passed to the President for these gifts.

The President further presented a beautifully bound book with blank leaves of linen-made paper for use as an Obligation-Book: a vote of thanks for this was passed.

The date of next Meeting was changed from April 2nd to March 19th.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 22nd, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Nineteen Members and one Visitor were present.

The following papers were read :—

1. Note on an occurrence of Mirabilite : by Dr. C. O. Trechmann (p. 73).

2. On a question relative to extinction-angles in rock-slices : by Mr. A. Harker (p. 66).

3. A new device for separating minerals by heavy liquids : by Mr. Harold B. Hartley.

4. On the arrangement of the chemical atoms in calc-spar and in some other crystals : by Mr. W. Barlow.

5. Addition to a former note on the rotation of points and planes : by Mr. R. W. H. T. Hudson. (Communicated by Professor Lewis.) (p. 71).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 19th, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Lieutenant D. St. A. P. Weston, R.N., was elected an Ordinary Member of the Society.

Reported that Mr. George Abbott, M.R.C.S., and Mr. Herbert Thomas Burls, F.G.S., had been proposed as candidates for the Ordinary Membership of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 19th, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Thirteen Members were present.

The election of Lieutenant D. St. A. P. Weston, R.N., to the Ordinary Membership of the Society was confirmed.

The following papers were read :—

1. Notes on an occurrence of minerals at Haddam Neck, Connecticut, U.S.A. : by Mr. H. L. Bowman.

2. On Calaverite from the Cripple Creek District : by Mr. G. F. Herbert Smith : with chemical analysis by Mr. G. T. Prior.

3. On the arrangement of the chemical atoms in Boracite and Cassiterite : by Mr. W. Barlow.

Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1900.

RECEIPTS.

	£ s. d.	£ s. d.
Balance from year 1899		92 19 11
Subscriptions:—		
(1) In advance	1 1 0	
(2) Current	42 0 0	
(3) In arrear	5 5 0	
		48 6 0
Entrance Fees and Compositions		47 5 0
Sale of Publications by publishers		25 5 0
Authors' Extra Copies		1 16 5
Dividends on Stock		12 13 9
		£228 6 1

PAYMENTS.

	£ s. d.	£ s. d.
Printing and Stationery		60 6 3
Illustrations		21 11 2
Attendants' Fees at Meetings		1 6 0
Clerk's Fee in charge of Stock (1899)		1 1 0
Postage		2 7 0
Commission on Cheques		0 0 6
Investments and Brokers' Commission		62 13 9
Balance at Bank	£75 8 4	
,, in Office	3 12 1	
		79 0 5
		£228 6 1

Examined and compared with the vouchers and found correct. (Signed)

BENEDICT KITTO, } *Auditors.*
J. H. COLLINS, }

LIABILITIES.

	£ s. d.
Printing No. 58 of the Journal	51 9 0
Miscellaneous Printing, including the Bye-Laws and List of Members	6 11 0
Clerk for care of Stock in 1900	1 1 0
Postage	0 17 1
Excess of Assets over Liabilities	585 8 4
	£645 6 5

ASSETS.

	£ s. d.
Balance as above	79 0 5
Subscriptions unpaid	15 15 0
Stock in 2¾ Consols: £526 11s. 1d., valued at 96	505 9 7
Dividend on Stock, January 1901	3 8 9
Sale of Journal, 1900	20 17 5
Arrears of Sales	2 15 3
Authors' Copies	18 0 0
	£645 6 5

The number of Life-Members on December 31st, 1900, was 52.

MEMO.—The Stock of Publications and the Value of the Library are not included in the above Assets.

(Signed) F. W. RUDLER,
Treasurer.

THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

No. 59. MAY, 1901. Vol. XIII.

On the Meteoric Stones which fell near Zomba, British Central Africa, on January 25th, 1899: with notes on the chemical analysis of such bodies. [With a map of the District, Plate I].

By L. Fletcher, M.A., F.R.S.,

Keeper of Minerals in the British Museum.

[Read, in sections, on June 20th, 1899, April 3rd, 1900, and June 19th, 1900, respectively.]

Part I.—The Circumstances of the Fall of the Stones.

ON January 25th, 1899, at 7.54 a.m., a loud noise as of an explosion was heard at the settlement of Zomba, British Central Africa, and for many miles around; almost simultaneously therewith, several small stones were seen to reach the earth in the neighbourhood of Zomba and were collected by the observers of their fall.

Mr. Alfred Sharpe, C.B., His Majesty's Commissioner and Consul-General for the Protectorate of British Central Africa, Mr. J. F. Cunningham, Secretary to the Administration, and Mr. J. McClounie, the Acting Collector of Revenues, on hearing the detonation, surmised that it had an origin in the entry of a meteorite into the earth's atmosphere, and with praiseworthy zeal and energy at once proceeded to collect, by aid of the telegraph and by personal interviews with the witnesses, all the reliable evidence that could be obtained relative to so extraordinary a

phenomenon. A Report, embodying this information and the notes made by Mr. Cunningham and Mr. McClounie, was sent by Mr. Sharpe to the British Museum; four of the stones, generously presented by Mr. Sharpe, Mr. Cunningham and Mr. McClounie, were forwarded at the same time for scientific examination and for subsequent preservation in the Meteorite Collection of the Museum.

The details given in the Report may be classified as follows:—

Luminous Meteor and Trail.

[*Zomba.*] "There being much cloud at the time, nothing was visible to indicate that a meteorite had entered the earth's atmosphere."

[*Blantyre.*] "A native named Bwanali, who was sitting in the open near the Government buildings, saw, a little before 8 a.m., a star of exceptional brilliancy pass across the sky in the direction of Lake Shirwa (roughly, west to east)." "A native capitao in the employment of Mr. James Lindsay makes a similar statement, and adds—it left a trail or tail behind it."

[*Chiromo.*] "Mr. H. C. McDonald telegraphed that several natives saw the star and smoke. They stated that it appeared to pass over Cholo."

[*Fort Johnston.*] "Mr. O. C. Ockenden, the Acting British Vice-Consul, telegraphed that the meteorite had been seen from Fort Johnston."

[*Chengali's village.*] "Sergeant-Major Bandawe, of the British Central Africa Rifles, who was on his way to Zomba, saw the meteor when he was at Chengali's village to the west of Lake Pamalombe. It left a trail, and exploded in the direction of Chikala."

Owing to the cloudy state of the sky the luminous meteor was thus seen from only a small number of places, and presumably for only small portions of its path. It must have been far above the clouds, for it was seen from places 130 miles apart. The meteor appears to have been travelling in an approximately easterly direction, and was seen to explode when near a line drawn from Lake Pamalombe to Chikala.

Detonation.

(*a*). *Places at which it was heard.*

[*Top of Mt. Zomba.*] Mr. Sharpe says:—"I heard one very loud report."

[*Zomba.*] Mr. Cunningham says:—"There was heard a crash like thunder."

[*Blantyre.*] "The native Bwanali heard an explosion like a crash of thunder. A native capitao in the employment of Mr. James Lindsay makes a similar statement."

[*Chikwawa.*] "Mr. J. O. Bowhill, the Judicial Officer at Chikwawa, heard the explosion as he was standing near his house. It seemed to him to come from the direction of Blantyre."

[*Katunga.*] "Mr. C. B. Vertue, the Agent of the African Lakes Company, made inquiries, and states that the explosion was heard by Muri (a native servant), 'James' and Mgano (capitaos), Njeresa and Mpeni (natives in charge of cattle).

"A native from Katunga's village came in to Chikwawa and told the Collector of Revenues that the explosion had been heard in that village."

[*Chiromo.*] "Mr. H. C. McDonald telegraphed that several natives heard the explosion."

[*Fort Johnston.*] "Mr. O. C. Ockenden telegraphed that the explosion had been heard at Fort Johnston."

As far as could be ascertained, neither the luminous meteor nor the detonation had been remarked by any one at Kota-Kota, Nkata or Karonga, places which are north of Fort Johnston and lie on the western shore of Lake Nyasa; they are in telegraphic connection with Zomba.

(*b*). *Character of the Detonation.*

The character of the detonation as heard by an observer would vary to some extent according to his situation.

[*Zomba.*] Mr. J. F. Cunningham says:—"I heard a crash like thunder, the reverberations lasting for a few minutes afterwards. When I heard it, I suspected what it was, but thought it might possibly be a dynamite explosion on the road to the new Residency, where I knew the Road-Engineer, Mr. William Fletcher, and a party of men were at work. I sent an inquiry to Mr. Fletcher, and he sent back word that he also had heard the explosion, but that it had not occurred on the Road."

Mr. J. McClounie says:—"The loud report had the precision of a cannon. I was indoors at the time, but instantly rushed out to see what had happened. My attention was drawn towards the east by the continuous rolling noise. The natives also were looking in an easterly direction."

[*Top of Mount Zomba.*] This mountain rises to a height of 6,000 feet above the sea, and is on the western side of the settlement, which is

itself 2,900 feet above the sea. Mr. Sharpe says:—"I heard one very loud report; then for some two minutes a long rumbling or buzzing noise, gradually getting fainter and fainter; I should not call it reverberations."

[*Kuntamba's village.*] "The chief Kuntamba, at his village about three miles from the Residency, to the west of the road to Domasi, heard a noise like thunder."

[*Blantyre.*] "The native Bwanali heard an explosion like a crash of thunder."

The detonation was thus a single one; at Blantyre and about 50 miles away in the villages north-east of Zomba it was as loud as thunder: it was heard also at Chiromo, about 90 miles south of the settlement of Zomba, and also beyond Fort Johnston, which is at a distance of 70 miles to the north of Zomba; to the observers at Zomba itself the sound seemed to come from the east.

Fall of Stones.

About an hour after the detonation had been heard, news reached the Residency that several stones had fallen in native villages on the eastern slopes of Mount Zomba. As many as ten were ascertained to have been found, and these have been preserved: only those stones were discovered which fell near to people or houses, and possibly they form only a small proportion of those which actually reached the earth.

The following is the history of the individual stones:—

Stone No. 1. Weight 2 oz. (57 grams). Fell at Kuntamba's village, about three miles from the Residency, to the west of the road going to Domasi. The chief Kuntamba gave the following account to Mr. Cunningham:—"This morning I was standing near my house when I heard something fall on the rock there" (pointing to a fairly level slab of granite, measuring 20 feet by 12 feet, near his house). "Immediately after, I heard a noise like thunder. I went to the rock and saw where a stone had fallen, and I picked up some small bits."

Mr. Cunningham adds:—"There was a large crowd of the village people present when the chief told me this, and two of them, Matendu and Laici, personally vouched for its accuracy. The fragment has only a small portion of outer crust. It is the largest of the pieces found at this spot."

Stone No. 2. Weight 4½ ozs. (128 grams). Fell at Kumpamba's village, 3 miles from the Residency along the Domasi road. The fall was witnessed by the chief and others. It is the smallest of the completely encrusted stones.

Stone No. 3. Weight 1 lb. 3 ozs. (539 grams). It was seen by a native to fall on the outskirts of the last-mentioned village. It is incomplete, a large piece having been broken off through impact against a stone when it fell. Presented to the British Museum by Mr. McClounie.

Stone No. 4. Weight 3 lbs. 5 ozs. (1502 grams). Fell on the border of a new garden on the verge of the forest about 400 yards to the south of the Likangala River, near Chiropa s village. A native was hoeing in the garden when the stone fell. The place was stony, and a corner of the meteoric stone was chipped off by the fall.

Stone No. 5. Weight 12½ ozs. (354 grams). Fell at Kampunga's village on Buchanan's Estate. "It was about noon when we (Mr. Ravenor and Mr. Cox) got to Kampunga's village (to inquire about the stone reported by Mr. Cunningham to have fallen there). We found the village people squatting round the stone in a circle, discussing the 'miracle' as they called it. No one had touched or approached the stone, and when we arrived it was still lying where it had fallen. The story of its advent was given as follows:— 'A woman was pounding corn under a tree, within about ten yards of her hut, when the stone fell. The whole village heard the detonation immediately afterwards, and gathered to where the woman was standing to view the stone. They were afraid of it, thinking it enchanted, and they sat at a distance round it, each giving a version of its probable origin and meaning.' It fell on hard ground, but, as there were no rocks about, I (Mr. Ravenor) was able to dig it up complete. It is covered with crust."

Stone No. 6. Weight 5 lbs. 12½ ozs. (2622 grams). Fell to the south of the Likangala River, to the west of Stone No. 4. It is the largest stone found, is completely encrusted, and has the usual pittings.

Stone No. 7. Weight 1 lb. 13 ozs. (822 grams). Fell at Chope's village, near Songani. It is probably only part of the fallen stone, for one large surface is not encrusted. Presented by Mr. Cunningham to the British Museum.

Stone No. 8. Weight 1 lb. 6½ ozs. (638 grams). Fell at Chirunga's village, two miles from the Residency, near the Domasi road. The side shown by a photograph of the stone is completely covered with crust.

Stones Nos. 9 and 10. Weights 14½ ozs. (411 grams) and 1 lb. 1 oz. (482 grams), respectively. Both of them fell at Kanyama's village,

and have been presented by Mr. Sharpe to the British Museum; they are almost completely encrusted stones. "Several people heard them crashing through the trees, and after a search found first one stone and, later on, the other."

Mr. McClounie says that one small stone in its fall cut a twig from the branch of a tree; this was two miles from Zomba, off the Liwonde road; several of the other pieces were picked up at or near this place.

As the meteorite travelled in a more or less easterly direction and reached the ground only a short distance from Zomba (Plate I), and the detonation seemed to the observers at Zomba itself to come from the East, it follows that the detonation is really a consequence of the break-up of the meteorite, and not, as has been sometimes suggested, due to the rush of air into the vacuum left behind the meteorite during its flight.

Area of Distribution of the Stones.

Mr. McClounie says:—"As far as I know at present the area over which stones have fallen is about 9 miles long and 3 miles wide. Whether any fell outside this area may never be known." [The positions of the stones as indicated in the map, Plate I, must be only approximate].

The dimensions thus assigned by Mr. McClounie are exactly identical with those of the area over which the stones were distributed in the case of the meteoritic fall at Knyahinya, Hungary, on 9th June, 1866. The area of distribution of the stones, in the case of a meteoritic shower, has rarely been found to measure more than ten miles by three.

The two heaviest stones, Nos. 6 and 4, weighing respectively 5 lbs. 12½ ozs. and 3 lbs. 5 ozs., were found at the southern end of this area. The next largest, No. 7, still weighing 1 lb. 13 ozs., and probably not more than half of the stone which fell, was at the northern end of the area, and not far from the smallest completely encrusted stone, No. 2, weighing 4½ ozs.; the complete stone, No. 7, may have really been the largest which fell. Stones Nos. 9 and 10, weighing respectively 14½ ozs. and 1 lb. 1 oz., were also found north of the smallest stone.

The area of distribution on the earth's surface of the stones of a large meteoritic shower is usually, not always, elongated in the direction of flight of the luminous meteor, and the stones are generally distributed within this area approximately according to size, the larger ones being near the end towards which the meteor's flight was directed. A distribution precisely according to size would be a necessary result of the resistance of the air on the individuals of an at first closely packed swarm of similar meteoric stones moving through the earth's atmosphere in a

direction inclined to the vertical, if each stone remain unbroken during its flight. But an admixture of sizes may result in various ways. For instance, a stone may be broken up into scattered unequal fragments at a point in its passage through the atmosphere such that the subsequent path of the fragments is not long enough for the differentiating effect of the resistance of the air to render of no moment their initial scattering in various directions.

Having regard to such considerations, it will be seen that the number of stones found at Zomba is too small and the sizes are too intermingled to admit of any sound inference as to the direction of the meteor's path from a mere study of the distribution of the fallen material, but the distribution, especially if No. 7 was really the largest stone, is not inconsistent with the direction suggested by the observations already referred to. It seems likely that the stones resulted from the breaking up of a single mass within the earth's atmosphere: there was only one detonation, and presumably only one important epoch of fracture; as the stones are completely encrusted, the scattering of the fragments must have taken place at a point where their velocity was high enough to cause superficial heating to a high temperature. As there is no mention, in the Report, of deep penetration of the ground, it is probable that the velocity was comparatively small at the time of impact on the earth's surface.

Material of the Stones.

It may be added that the material of the stones was observed to be unlike that of any of the rocks of the district, and that the specific gravity of two of the stones was determined by Mr. T. J. Binnie, Acting Chief Surveyor, to be 3·5, which is much higher than that of any of the Zomba rocks; further, Mr. McClounie noticed the numerous metallic particles glittering on the fractured surface, and proved that the material has a directive action on a compass-needle.

Part II.—The Characters of the Stones.

The Crust.

The crust is brownish-black to black in colour; it is mostly smooth, but in parts is scoriaceous or wrinkled; it shows occasional protuberances. The crust is dull, but a spot, 7 mm. in diameter, on Stone No. 7 is lustrous: in the case of Stone No. 3 a patch of crust, 3 mm. by 4 mm., is transparent and of a light green colour. On Stone No. 7 there is a linear ridge which can be traced round one of the edges of the stone for a

distance of 70 mm.; a fracture of the crust shows that the ridge is the prolongation of a black vein in the stone. The thickness of the crust averages 0·5 mm. and reaches a maximum of 1 mm.

Each of the stones Nos. 9 and 10 has one side different in aspect from the others; instead of being comparatively uniform in curvature, this side is covered with pit-like depressions.

The Fractured Surfaces.

The fractured surface of Stone No. 7 shows part of a broken troilite-nodule, 5 mm. wide, of irregular form; an unbroken chondrule, 2 mm. in diameter, projects above the general surface; in one part is a material of vitreous lustre, curved, nearly linear and 2 mm. long.

A freshly-made fracture of Stone No. 3 varies in parts from white to whitish-grey in colour: one portion shows a dark grey oval patch, 12 mm. by 7 mm.; another was found to break through a beautifully regular bluish or bluish-grey chondrule, 2½ mm. in diameter.

Specific Gravity.

The specific gravity was determined for a fragment, weighing 13·8522 grams, of Stone No. 3: the fragment was free from crust and exactly similar in aspect to a fragment of the same stone used for chemical analysis. The loss of weight in distilled water at 20·2° C. was 3·8973; the air was extracted from the pores by the air-pump. Duly corrected, the weight of one cubic centimeter at 20·2° C. is 3·545 grams.

Microscopic Examination.

Thin sections prepared for the microscope, when examined with the unassisted eye by reflected light, show small, very irregularly shaped, lustrous, metallic constituents (nickel-iron), and also still smaller dull opaque black particles (completely enclosed nickel-iron, troilite or chromite), dispersed through a greyish-white stony material: one of the five sections shows part of a black vein. By ordinary transmitted light the stony material is seen, with the aid of the microscope, to consist almost wholly of a nearly colourless crystalline groundmass, constituted of crystals which are chiefly small and rarely show any boundary due to the section of a natural face. Between crossed Nicols the groundmass (olivine, enstatite and plagioclastic felspar) is seen as a bright small-grained mosaic (grey, yellow, red, blue and green) interspersed with small and large crystals (the latter chiefly olivine); here and there, small quantities of a mineral nearly or quite free from cracks and polarising in grey tints (probably plagioclastic felspar) fill up intervening irregular

spaces and mould the other crystallised material: the general aspect being very like that of sections of the meteorites of Linn County, Grossliebenthal, Girgenti and Alfianello. Enclosed in the groundmass, and intimately connected therewith, are some chondrules, few in number and almost all of them white. One of them is perfectly round and has a well marked shell, the whole of the kernel and the shell extinguishing the light simultaneously (monosomatically) and being constituted apparently of short blocks, characters which are very common in olivine-chondrules: further, as is not unusual, particles of nickel-iron are closely grouped round the greater part of the outer boundary of the shell. A second chondrule is very similar, but no shell is evident and the block-structure is less marked. A third chondrule, almost monosomatic, shows a triple shell. Other chondrules are polysomatic, being composed of several crystals having different optic orientations. In each of two slides is a section of a chondrule which, looked at with the unassisted eye, is black by reflected light; with the microscope and crossed Nicols, it is seen to consist of a transparent substance polarising in grey tints (probably plagioclastic felspar) and enclosing opaque particles which are densely packed in the centre and are almost absent near the circumference of the chondrule: a similar black chondrule is shown by a section of the Grossliebenthal meteorite. Some patches of material seen in the sections are micro-crystalline aggregates and are possibly enstatite.

Chemical Examination.

As there is necessarily more or less speculation in the interpretation of the results observed during the chemical examination of a mechanical mixture of compounds having one or more chemical elements in common, the observations and calculations are conveniently kept quite distinct from each other and recorded in separate sections. Both are given in detail, so that future investigators of meteoric stones may know the kind of difficulty which presents itself in such an inquiry, and may form an estimate of the weight to be assigned to the numerical results arrived at.

Section I. Observations.

WEIGHTS OBTAINED IN THE COURSE OF THE CHEMICAL ANALYSIS.

Magnetic Separation.

1. A freshly broken, easily frangible, crustless fragment of Stone No. 3, weighing 14·6 grams, was crushed in a steel mortar, and afterwards pulverised, in small portions at a time, in an agate mortar; it was impossible, owing to the presence of malleable grains of nickel-iron alloy,

to reduce the material in this way to a fine powder of uniform composition. The alloy was next magnetically extracted by means of a seven-toothed iron comb, such as is used by grainers, but which had been magnetised: the powder being worked through in small quantities at a time. The residual powder was again pulverised in the agate mortar and the magnetic separation repeated. At the end of a series of operations the material had been divided into two parts; the one, attracted, weighing 2·0144 grams; the other, unattracted, weighing 12·4208 grams; the total quantity of material available for analysis being thus 14·4352 grams. The attracted material consisted of particles of different sizes; some of them were about a millimeter in diameter; much of the remainder consisted of smaller but still coarse grains, and another portion consisted of particles which were extremely minute and thus readily oxidisable on exposure to air or moisture: the unattracted material was an impalpable powder of a bluish-grey colour and apparently quite free from iron-rust.

ATTRACTED MATERIAL: TOTAL WEIGHT 2·0144 GRAMS.

Treatment with solution of mercuric ammonium chloride.

2. 0·7421 gram of the attracted material was transferred to a small flask and treated with cold mercuric solution in an atmosphere of hydrogen as described in a previous paper,[1] the flask and contents being frequently shaken during the daytime; after the action had proceeded for some time, the liquid was quickly filtered, and the insoluble matter was washed with cold water which contained a little mercuric solution and had been boiled to expel dissolved air. For each of the first two extractions 200 cc. of the mercuric solution were used; for each of the next five, 100 cc.: the first extraction was allowed to proceed for 3 hours; each of the next four, for 24 hours; the sixth, for 96 hours; and the seventh, for 24 hours.

Each of the extracts was acidified, heated to boiling, and precipitated by sulphuretted hydrogen, and the several filtrates were evaporated to dryness. The residue from the third extract showed by its colour that an appreciable amount of alloy had been extracted by the mercuric solution, and there was still an evident tinge of colour even in the residue from the seventh extract; the coloration was much smaller in the case of the fourth and fifth extracts than in that of the third, while those of the sixth and seventh, though evident, were only just appreciable; the last

[1] Mineralogical Magazine, 1894, vol. 10, p. 293.

two were of about equal intensity although the sixth extraction had occupied four days and the seventh only one. There was by this time much admixed mercury and mercurous chloride, protecting the material to some extent from the action of the solvent; possibly, also, some of the particles of the alloy were so large as to require a very prolonged action to produce solution; possibly some had been superficially oxidised and were partially sheltered by the oxide from contact with the liquid: undissolved particles of alloy are very liable to be superficially oxidised when exposed to the air during the filtration. The extraction, although incomplete, was accordingly not further proceeded with at this stage.

The various precipitates produced by the sulphuretted hydrogen were ignited and the mercury driven off; there remained a small brownish residue, which was soluble in warm hydrochloric acid, and gave a rich yellow solution; it was again precipitated by sulphuretted hydrogen, and the filtrate, which may contain a little iron carried down by the mercuric sulphide, was added to the main extracts. The brown precipitate weighed after ignition 0·0001 gram, and was found to be due to the presence of copper. The extracts having been collected together, the iron was oxidised, and at the same time the ammonium chloride decomposed, by evaporation with strong nitric acid; the residue was then treated with strong hydrochloric acid and again evaporated to dryness. From the dilute solution the iron was separated from the nickel by a fourfold precipitation with sodium acetate; probably two precipitations would have sufficed, for it was afterwards found that the nickel separated by the third and fourth precipitations was scarcely large enough to be appreciable. After a final precipitation with ammonia and ignition, the precipitate weighed 0·4933 gram. Of this, 0·4054 gram was ignited in a current of hydrogen and treated with hydrochloric acid; the insoluble SiO_2 weighed 0·0028, and was probably due to the action of the voluminous boiling liquid on the glass during the four precipitations of the iron. The dissolved iron was precipitated by ammonium sulphide, and the filtrate, which showed no trace of nickel (thus indicating the completeness of the separation from that metal), was evaporated to dryness; the ammoniacal salt was expelled by gentle ignition: from the residue then obtained, a small quantity of phosphorus (presumably due to oxidation of schreibersite, phosphide of iron and nickel) was eventually separated by molybdic solution and afterwards by magnesia mixture: the $Mg_2P_2O_7$ weighed only 0·0005.

The nickel and cobalt were twice precipitated by caustic potash and bromine water; as oxides they weighed 0·0606, as metal 0·0487. The

cobalt was separated from the nickel by the nitrite method and converted into potassium cobalt sulphate ($3K_2SO_4 \cdot 2CoSO_4$) ; this weighed 0·0166.

3. The residue from the action of the mercuric solution was in two parts: one part, still adherent to the filter, weighed after ignition (and therefore partial oxidation) 0·0019 gram; the other part, which had been washed from the filter, contained some bright metallic spangles (probably schreibersite, phosphide of iron and nickel) mingled with much mercurous chloride, mercury and coarse grains of silicate; further, much of the material was found to be still magnetic; after being heated in a current of hydrogen to a temperature just below visible red heat until no further volatilisation took place, it weighed 0·3366 gram. The residual powder, instead of consisting of light coloured silicates, as had been expected, was almost wholly of a dull black colour, but further contained the lustrous metallic spangles already referred to; and the whole was attracted by the compass-needle, showing that the coarse grains of silicate, obviously present, themselves contained magnetic matter. It was inferred that the powder consisted largely of magnetic oxide of iron; the residue was therefore heated to low redness in a current of hydrogen, again submitted to the action of the mercuric solution, transferred back to the boat and again heated in hydrogen; as the residue was not much diminished and was still of a dull black colour, the operations were repeated, the temperature being raised to full red heat, but with a similar result. After a further extraction with mercuric solution, the residue was again heated in hydrogen to a full red heat and weighed (0·2759 gram). The part adherent to the filter weighed, after ignition, 0·0091 gram. The combined extracts yielded, after a double precipitation with sodium acetate, Fe_2O_3 0·0439 and Ni(Co) 0·0135.

4. As the total residue had only been reduced by the last operations from 0·3366 gram to 0·2850 gram and was not appreciably changed in aspect, it was decided to treat the residue with hydrochloric acid and to analyse it in the same way as the unattracted material.

0·2757 gram was treated on the waterbath with dilute HCl (s. g. 1·06); there was immediate effervescence, which lasted for ten minutes. From this it is inferred that particles of alloy had been protected from the mercuric solution by a coating of oxide or by enclosure in grains of olivinic silicate, probably in both ways. The silica set free by the acid was separated by means of sodic solution and weighed (0·0447 gram). The residue washed from the filter weighed 0·1280 and was white; the part adherent to the filter weighed, after ignition, 0·0129 gram.

From the acid solution the following weights were obtained:—

Fe_2O_3,SiO_2 0·0450 (yielding SiO_2 0·0013, presumably due to the action on the vessels).

Ni(Co)O 0·0088; yielding Ni(Co) 0·0072.

CaO 0·0036, probably almost entirely due to the action on the glass and porcelain during the precipitation of the iron and the separation of the nickel.

$Mg_2P_2O_7$ 0·1187.

UNATTRACTED MATERIAL: TOTAL WEIGHT 12·4208 GRAMS.

Extractions with Water, Alcohol and Ether.

5. 1·0017 grams of the unattracted material were transferred to a platinum dish and covered with 100 cc. of distilled water; after being boiled the solution was allowed to cool and then filtered without prolonged standing; the filtrate was opalescent. It was evaporated to dryness, 100 cc. of water were again added, and the liquid was boiled. It was afterwards filtered, the filter being on this occasion left unwashed; the filtrate was now limpid and yet contained all the soluble matter; the powder adherent to the dish and filter was doubtless finely divided silicate which had been in a state of suspension and had caused the opalescence. The soluble residue yielded by the evaporation of the filtrate weighed 0·0026 gram, or 0·26 per cent.

Its solution was inactive to litmus and turmeric, and gave a rich yellow colour to the Bunsen flame. On spontaneous evaporation it began to deposit a precipitate as soon as it became concentrated, the liquid becoming quite milky in appearance when its volume had decreased to a cubic centimeter; after the evaporation was complete, the residue, examined with the microscope, was seen to consist mostly of small crystals optically isotropic, but of no distinct form; there were a few isolated groups of radiating birefringent plates, and also some isolated lacicular crystals having straight extinction. The solution gave no precipitate with ammonia and ammonium chloride, even on boiling, but was found to contain calcium and a minute amount of magnesium. It contained sulphate in considerable quantity, but only an extremely minute trace of chloride; no phosphate could be detected. This is virtually the same result as was obtained in the examination of the Makariwa stone[1]; in that case it was inferred that the salts found in the extracting water were due to a partial oxidation of the protosulphide of iron (troilite) to

[1] Ibid. p. 297.

sulphate, and to the subsequent action of the dissolved sulphate on the silicates, but it was uncertain whether the oxidation had taken place during the aqueous extraction itself or while the stone was lying buried in the ground. As the Zomba stone was quite fresh, it may be concluded that the oxidation of the troilite takes place during the boiling, and that the soluble salts may be accounted for without being regarded as original constituents of the meteoric stone.

The residue left after treatment with the distilled water was digested with 50 cc. of absolute alcohol for three days, and afterwards with 50 cc. of ether for 30 minutes; in neither case was anything weighable extracted.

Determination of chromite: absence of diamond.

6. The same residue was treated finally with hydrofluoric and sulphuric acids. The insoluble material was transferred to a watch-glass and microscopically examined; as it was entirely opaque and of metallic lustre, no diamond could be present; after ignition it weighed 0·0035 gram and gave the reactions of chromium. The above number corresponds to 0·35 per cent. of chromite in the unattracted material; but it is only a minimum, for part of the chromite, being very finely divided, would probably yield to the attack of the acid and be carried into solution.

Determination of sulphur and phosphorus: absence of titanium.

7. 0·9920 gram, treated in the way described in a previous paper[1], yielded $BaSO_4$ 0·1481 and $Mg_2P_2O_7$ 0·0024. During these operations, it was ascertained that titanium was absent.

Determination of the alkalies.

8. 0·4815 gram, analysed by the Lawrence Smith method, gave:—Sodium and potassium chlorides 0·0135; tested with a small spectroscope only the sodium line was visible: K_2PtCl_6 (free from filter) 0·0040; adherent to filter and ignited, 0·0036.

A blank experiment simultaneously made with the same reagents gave:—Sodium and potassium chlorides, 0·0021: K_2PtCl_6 (free from filter) 0·0056; adherent to filter and ignited, 0·0012.

Treatment with mercuric solution.

9. 4·9856 grams were treated with mercuric solution in an atmosphere of hydrogen, as already described; the extraction proceeded for 24 hours and was performed three times. The first extract was appreciable; the second and third showed only slight tinges of colour.

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[1] Ibid. p. 298.

The combined extracts yielded :—

CuS (ignited in air) 0·0003.

After oxidation of the iron and decomposition of the ammonium chloride, the residue was green, showing its comparative richness in nickel : the solution gave

Fe_2O_3,SiO_2 0·0025, yielding SiO_2 0·0004.

NiO 0·0007.

CaO 0·0040, probably almost entirely due to the action on the glass and porcelain during the precipitation of the iron and the removal of the nickel.

$Mg_2P_2O_7$ 0·0037.

Treatment with hydrochloric acid and sodic solution : First Portion.

10. 2·5065 grams of that part of the unattracted material which had not been subjected to the action of the mercuric solution were extracted three times with dilute hydrochloric acid, according to the method described in a previous paper.[1] In this case the extracts were decanted from the undecomposed material (admixed with free silica), and the decanted liquid and the undecomposed material separately evaporated to complete dryness ; the continued action of the acid on the main material during the evaporation was thus prevented, though a certain amount of action on the finely divided silicate suspended in the liquid cannot be avoided. The free silica was next extracted with strong solution of sodium carbonate (to which a piece of caustic soda had been added) ; in the last stages of the washing of the undecomposed material a little of the finely divided silicate passes through the pores of the filter ; the amount of this was afterwards determined. The sodic extract was examined, not only for silica, but for bases.

The following numbers were obtained :—

a. Undecomposed material : part washed from filter, 0·9186 ; part adherent to filter and ignited, 0·1328.

b. The acid solution yielded : —

Fe_2O_3,Al_2O_3,SiO_2 0·4639 ; of this 0·4150, after the iron had been expelled by the Deville-Cooke method, gave Al_2O_3,SiO_2 0·0055, and from this 0·0019 of SiO_2 was obtained.

MnS 0·0068.

NiO 0·0001.

The rest of the acid solution, containing the calcium and magnesium, was lost.

[1] Ibid. p. 302.

c. The sodic solution yielded :—

SiO_2, with trace of undecomposed material, 0·4909. After treatment with HF and H_2SO_4 and subsequent ignition, 0·0039. The residue thus obtained was partly reddish and partly white ; the former was oxide of iron, the latter was found to contain magnesium ; the residue was thus due to the trace of undecomposed material which had passed through the pores of the filter.

Fe_2O_3,Al_2O_3,SiO_2 0·0048, yielding SiO_2 0·0031 and the Fe_2O_3, as judged from the colour, being small.

CaO 0·0020, partly due to action on the vessels.

Treatment with hydrochloric acid and sodic solution : Second Portion.

11. 2·7333 grams of the unattracted material, which had been subjected to the action of the mercuric solution (§ 9) and still contained mercury and mercurous chloride, treated in the above way with hydrochloric acid, gave the following :—

a. Undecomposed material : part washed from filter, 1·0981 ; part adherent to filter and ignited, 0·0516.

b. The acid solution yielded :—

Fe_2O_3,Al_2O_3,SiO_2 0·5013 ; of this 0·4169 gave Al_2O_3,SiO_2 0·0044, which yielded SiO_2 0·0028.

MnS 0·0074.

NiS (after ignition in air) 0·0012.

(CaO, due to action on the vessels, 0·0022.)

CaO 0·0105 (in all the analyses the calcium was twice precipitated).

SiO_2 0·0061 was obtained after the decomposition of the ammonium chloride by nitric acid, and is a measure of the amount of action on the vessels.

$Mg_2P_2O_7$ 1·3834.

c. The sodic solution yielded :—

SiO_2, with trace of undecomposed material, 0·5301.

After treatment with HF and H_2SO_4 and subsequent ignition, 0·0017.

Fe_2O_3,Al_2O_3,SiO_2 0·0065 ; of this 0·0046 gave Al_2O_3,SiO_2 0·0032, which itself yielded SiO_2 0·0007.

CaO 0·0013 (probably due, in part at least, to the action on the glass and porcelain).

d. Another portion, weighing 2·0583 grams, lost 0·0512 of volatile material when heated, in a current of hydrogen, in a platinum boat

contained in a platinum tube supported in an oven at 298° C.; at this low temperature the troilite remains unaffected.

Treatment with hydrochloric acid and sodic solution: Third Portion.

12. 2·0317 grams of the unattracted material, which had been subjected to the action of the mercuric solution (§ 9), but from which the volatile material had been removed by heating at a low temperature in a current of hydrogen, gave the following numbers:—

a. Undecomposed material: part washed from filter, 0·8107; part adherent to filter and ignited, 0·0241.

b. The acid solution yielded:—

Fe_2O_3,Al_2O_3,SiO_2 0·3775; of this 0·3352 gave Al_2O_3,SiO_2 0·0018, and the latter when analysed yielded Al_2O_3 0·0001, SiO_2 0·0016.

CuS (ignited in air) 0·0003.

MnS 0·0056.

Ni(Co) 0·0010.

CaO 0·0107.

SiO_2 0·0067 was obtained after the decomposition of the ammonium chloride by nitric acid, and is a measure of the amount of action on the vessels.

$Mg_2P_2O_7$ 1·0958 (and this includes the calcium and aluminium due to the action of the nitric acid on the porcelain dish).

The sodic solution yielded:—

SiO_2, with trace of undecomposed material, 0·4208. After treatment with HF and H_2SO_4 and subsequent ignition, 0·0026.

Fe_2O_3,Al_2O_3,SiO_2 0·0069; of this 0·0047 gave Al_2O_3,SiO_2 0·0022, and the latter when analysed gave Al_2O_3 0·0024, SiO_2 0·0001.

(CaO, due to action on porcelain dish, 0·0012).

Examination of the blank sodic solution.

13. The amount of the alumina extracted by the sodic solution being appreciable though small, and the amount of sodic solution used being large, it was desirable to make similar experiments on the sodic solution itself. Taking the same amount of sodic solution (20 grams of crystallised sodium carbonate and $2\frac{1}{2}$ grams of caustic soda) as was used in the last analysis, the following numbers were obtained:—

SiO_2 0·0049.

Fe_2O_3,Al_2O_3,SiO_2 0·0009 (the alumina and silica being probably inappreciable).

CaO 0·0005.

CaO 0·0019, due to action on the porcelain dish.

$Mg_2P_2O_7$ *nil*.

Undecomposed Material: Specific gravity.

14. The material left undecomposed by the acid and sodic solutions was white in colour, but there was admixed with it a little black material of higher specific gravity than that of the silicate; the black material was found to be chromite. The specific gravity of the admixture was determined from 1·2831 grams of the material by means of a 3 cc. pycnometer. The usual corrections for the temperature of the water and for the displaced air being made, it was found that the weight of the material which occupies a cubic centimeter at 17° C. is 3·171 grams.

Undecomposed Material: Chemical analysis.

15. 0·8981 gram of the undecomposed material was fused with mixed potassium and sodium carbonates. There was a perceptible action on the platinum crucible involving the eventual separation of a little platinum from the magnesium pyrophosphate, but otherwise not interfering with the analysis. The chromite was partially decomposed, and the chromium which passed into solution manifested itself by the green colour of the oxides after the iron had been removed from the ignited precipitate by the Deville-Cooke method; the oxides of iron, aluminium and chromium had been twice precipitated together in dilute solution by the sodium acetate method and finally with ammonia; they were thus free from magnesium.

The following numbers were obtained:—

SiO_2 + chromite 0·5056.

Chromite, after treatment with HF and H_2SO_4, 0·0027.

$Fe_2O_3, Cr_2O_3, Al_2O_3, SiO_2$ 0·1545; of this 0·1201 yielded Cr_2O_3, Al_2O_3, SiO_2 0·0393, which itself on being analysed gave Cr_2O_3 0·0054, Al_2O_3 0·0314, SiO_2 0·0006, the loss being probably Al_2O_3.

MnS 0·0042.

CaO 0·0369 (a double precipitation with ammonium oxalate).

$Mg_2P_2O_7$ 0·5384.

16. *Alkalies.* 0·4994 gram of the undecomposed material, analysed by the Lawrence Smith method, gave:— Sodium and potassium chlorides 0·0183: K_2PtCl_6 (free from filter) 0·0079; adherent to filter and ignited 0·0025. During the operation the chromite was, partially at least, converted into chromate, and Cr_2O_3 0·0018 was separated from the alkaline solution before the mixed chlorides could be weighed.

Undecomposed material: Action of hydrochloric acid and sodic solution.

17. It is well known that the residue from the treatment with hydrochloric acid and sodic solution is far from insensible to the action of

those reagents; it became desirable to ascertain the amount of this action under similar circumstances to those of the analyses of the unattracted material itself.

1·0388 grams of the undecomposed material were therefore treated in the same way as the unattracted material. The following numbers were obtained:—

a. Residual material: part washed from filter, 0·8807; part adherent to filter and ignited, 0·0363.

b. The acid solution yielded:—

Fe_2O_3,Al_2O_3,SiO_2 0·0150; of this 0·0080 gave Al_2O_3 0·0005 and SiO_2 *nil*.

SiO_2 0·0022 was obtained from the solution, and is a measure of the action on the vessels.

CaO 0·0076.

After decomposition of the ammonium chloride by nitric acid, SiO_2 0·0033 and Fe_2O_3,Al_2O_3 0·0008 were separated from the solution, and were due to the action of the nitric acid on the porcelain dish.

$Mg_2P_2O_7$ 0·0649.

c. The sodic solution yielded:—

SiO_2, with trace of undecomposed material, 0·0763.

After treatment with HF and H_2SO_4 and subsequent ignition, 0·0014.

Fe_2O_3,Al_2O_3,SiO_2 0·0071; of this 0·0060 gave Al_2O_3,SiO_2 0·0052, and the latter when analysed gave Al_2O_3 0·0048 and SiO_2 *nil*.

CaO 0·0028.

[Further CaO 0·0016, due to action of nitric acid on the porcelain dish.]

$Mg_2P_2O_7$ *nil*.

Undecomposed material: Effect of ignition.

18. As the undecomposed material contains a considerable proportion of ferrous oxide, it was probable that ignition would appreciably increase its weight. It is necessary to determine the amount of this action, for that part of the silicate which is adherent to the filter cannot be weighed until after ignition.

0·0332 gram of the undecomposed material, after ignition with the gas blowpipe, became 0·0331; there was thus no appreciable change of weight, the increase of weight by oxidation being neutralised by loss due to volatilisation.

Undecomposed material: Effect of hydrofluoric and sulphuric acids followed by ignition.

19. Similarly, it is necessary to determine the effect of hydrofluoric and sulphuric acids, followed by ignition, in order to determine for each case the amount of the finely divided silicate which has passed through the pores of the filter and is admixed with the silica. It was found that 0·0696 gram of the undecomposed material gave after this treatment a residue which weighed 0·0572.

Action of nitric acid on the porcelain.

20. For the precipitation of the small amount of calcium, it is necessary to add to the solution enough ammonium oxalate to convert not merely the calcium itself, but also the magnesium, into oxalate, otherwise part of the calcium may remain in solution. The large amount of ammoniacal salt thus introduced has to be removed before the precipitation of the magnesium: if this is effected by evaporation and ignition, there is great danger of loss through spurting; if it is effected by evaporation with strong nitric acid, there is an appreciable action on the porcelain dish and the magnesium precipitate is not quite pure. The amount of action depends on the duration of the evaporation with nitric acid and on the amount of the latter; it will thus vary in different experiments. To gain some idea of the amount of the action, the silica and calcium thus brought into solution were on several occasions determined and have been recorded above:—

SiO_2 0·0061 (§ 11), 0·0067 (§ 12).
CaO 0·0036 (§ 4), 0·0040 (§ 9), 0·0020 (§ 10), 0·0013 (§ 11), 0·0022 (§ 11), 0·0012 (§ 12).

The mean of the numbers for the CaO is 0·0024; the weight of the corresponding $Ca_2P_2O_7$ would be 0·0054: this amount may therefore be properly subtracted from the determined weight of the $Mg_2P_2O_7$ when the amount of nitric acid used has been about the average.

Section II. Calculations.

Interpretation of the analytical results.

Atomic Weights.

21. The atomic weights used in the following calculations are those

recommended by Professor F. W. Clarke, in the Seventh Annual Report of the Committee on Atomic Weights[1], namely :—

Al	26·9	Fe	55·6	O	15·88
Ba	136·4	H	1	P	30·75
Ca	39·8	K	38·82	Pt	193·4
Cl	35·18	Mg	24·1	S	31·83
Co	58·55	Mn	54·6	Si	28·2
Cr	51·7	Na	22·88		
Cu	63·1	Ni	58·25		

It is convenient to make the calculations in the following order.

Undecomposed Material.

22. *Alkalies.* K_2PtCl_6 0·0079 (§ 16) corresponds to KCl 0·0024 ; 0·0025, adherent to the filter and ignited, if taken as Pt·2KCl, corresponds to KCl 0·0019 ; making altogether KCl 0·0035. From the blank experiment (§ 8), K_2PtCl_6 0·0056 and Pt·2KCl 0·0012 correspond respectively to KCl 0·0017 and KCl 0·0005 ; making in all 0·0022 ; as the direct weight of the chlorides was only 0·0021, the whole 0·0021 must have been potassium chloride. The potassium chloride due to the silicate is thus 0·0014. The mixed chlorides due to the silicate weigh 0·0183 (§ 16)—0·0021 (§ 8) or 0·0162 ; hence the NaCl due to the silicate is 0·0148.

These amounts of NaCl and KCl correspond respectively to Na_2O 0·0079 and K_2O 0·0009 for 0·4994 of undecomposed material, and to Na_2O 1·58, K_2O 0·18 per cent. ; no stress can be laid on the number for K_2O.

As the undecomposed material had been boiled three times, each time for five minutes, in a strong sodic solution, it is not inconceivable that soda might have been introduced into its composition. But the residue had been subjected to a very long continued washing to secure the complete removal of soluble matter ; further, there is already a certain amount of sodium in the mixed silicates before the digestion with sodic solution (§ 5, § 8), and a consideration of the weights of the soda in the mixed silicates and the undecomposed material suggests that the sodium is an original constituent of the latter.

23. 0·1201 (§ 15) of mixed oxides consists of Cr_2O_3 0·0054, Al_2O_3 0·0333, Fe_2O_3 0·0808 and SiO_2 0·0006 ; hence 0·1545 of mixed oxides

[1] Journ. Amer. Chem. Soc. 1900, vol. 22, p. 70.

consists of Cr_2O_3 0·0070, Al_2O_3 0·0428, Fe_2O_3 0·1039 (and SiO_2 0·0008, due to the action on the glass).

Cr_2O_3 0·0070 must have been originally present as chromite ($FeO \cdot Cr_2O_3$) and requires FeO 0·0033 ; chromite 0·0103 has thus been decomposed further, undecomposed chromite 0·0027 was admixed with the main silica. The total chromite was therefore 0·0130.

Fe_2O_3 0·1039 corresponds to FeO 0·0935 ; of this 0·0033 is due to chromite, leaving 0·0902 for the silicate.

MnS 0·0042 corresponds to MnO 0·0034.

Deducting 0·0054 (§ 20) from the weight obtained for the $Mg_2P_2O_7$ 0·5384, the pure $Mg_2P_2O_7$ is 0·5330, corresponding to MgO 0·1930.

For 0·8981 of undecomposed material (§ 15), Na_2O is 0·0141 and K_2O 0·0016 (§ 22).

Hence we have the following numbers :—

		Zomba. Percentages for silicate.	Zomba. Oxygen.		Linn County. Percentages for silicate.
Chromite	0·0130	—	—		—
SiO_2	0·5029	56·83	30·10		55·08
FeO	0·0902	10·19	2·26		13·58
MnO	0·0034	0·39	0·09	12·22	
MgO	0·1930	21·81	8·68		22·70
CaO	0·0369	4·17	1·19		2·85
Al_2O_3	0·0428	4·84	2·27		4·86
K_2O	0·0016	0·18	0·03	0·44	trace
Na_2O	0·0141	1·59	0·41		0·93
Total	0·8979	100·00			100·00
Weight taken	0·8981				

The percentage composition of the silicate approaches very closely to the corresponding silicate in the Linn County meteorite as analysed by Rammelsberg.[1]

24. The undecomposed material being insoluble in water, the alkalies must be present as constituents of an insoluble compound, presumably felspar; the presence of the latter is further suggested by the fact that the dyad constituents are insufficient to form an aluminous pyroxene with the alumina and silica.

[1] Monatsb. Ak. Wiss. Berlin, 1870, p. 458.

The CaO cannot be wholly present as a constituent of lime-felspar ($CaO \cdot Al_2O_3 \cdot 2SiO_2$); for in such case the oxygen of the Al_2O_3 must have been 3·57 instead of 2·27, without the alumina required for the soda-felspar being taken into account.

Hence it is reasonable to assume:—

1. That all the alumina is due to felspar (an admixture of albite and anorthite).

2. That all the alkali is due to felspar (albite).

3. That the excess of lime above that required to form felspar is a constituent of the remaining silicate (enstatite).

With these assumptions the following numbers may be obtained:—

The oxygen of $(Na,K)_2O$ being 0·44, that of the Al_2O_3 and SiO_2 forming albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) will be respectively 1·32 and 5·28. The total oxygen of the Al_2O_3 being 2·27, there is left 0·95 for the oxygen of the Al_2O_3 forming anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$); the oxygen of the corresponding CaO and SiO_2 will thus be respectively 0·32 and 1·28.

We therefore have the following distribution of the oxygen:—

		Total Oxygen.	Oxygen of— Enstatite.	Albite.	Anorthite.
SiO_2	...	30·10	23·54	5·28	1·28
FeO	...	2·26	2·26	—	—
MnO	...	0·09	0·09	—	—
MgO	...	8·68	8·68	—	—
CaO	...	1·19	0·87	—	0·32
Al_2O_3	...	2·27	—	1·32	0·95
K_2O / Na_2O	...	0·44	—	0·44	—

The total oxygen of the bases of the enstatite, namely 11·9, is slightly more than half that of the silica (23·54). On the other hand, the original constituents of the meteorite have been digested first with hydrochloric acid and then with sodic solution; the latter, while removing the free silica, would be expected to act to some extent on the silicates which resisted the acid, and to carry away the resultant silica, alumina and lime, leaving the corresponding oxides of iron and magnesia from the decomposed enstatite as part of the final residue.

25. The above distribution of oxygen corresponds to the following composition for the silicates themselves:—

	Enstatite.	Felspar. Albite.	Felspar. Anorthite.	Total.
SiO_2 ...	44·44	9·97	2·42	56·83
FeO ...	10·19	—	—	10·19
MnO ...	0·39	—	—	0·39
MgO ..	21·81	—	—	21·81
CaO ...	3·04	—	1·13	4·17
Al_2O_3 ...	—	2·78	2·06	4·84
K_2O ...	—	0·18	—	0·18
Na_2O ...	—	1·59	—	1·59
		14·52	5·61	
	79·87	20·13		100·00

26. The composition of the above felspar is

		Percentages.	Calculated for Oligoclase (Ab_3An_1).
SiO_2	12·39	61·55	62·1
CaO	1·13	5·61	5·3
Al_2O_3	4·84	24·04	23·9
K_2O	0·18	0·90 } 8·8	8·7
Na_2O	1·59	7·90 }	
	20·13	100·00	100·0

27. The percentage composition of the above enstatite is

	Zomba Enstatite.	Lodran Enstatite.
SiO_2 ...	55·64	55·35
FeO ...	12·76	12·13
MnO ...	0·49	—
MgO ...	27·31	32·85
CaO ...	3·80	0·58
	—	Al_2O_3 0·60
	100·00	101·51

The numbers thus obtained for the Zomba enstatite are very similar to those obtained by Professor Tschermak for the Lodran enstatite: in the latter case the enstatite grains were so coarse that they could be picked out and a sufficient amount be separated for a special analysis.[1]

[1] Sitzungsb. Ak. Wien, 1870, Band 61, Abtheil. 2, p. 465.

28. The mineral composition of the undecomposed material is

Enstatite	...	79·87	78·71
Oligoclase	...	20·13	19·84
Chromite	...	1·47	1·45
		101·47	100·00

Specific gravity of the Zomba enstatite.

29. Since the proportions by weight of the three constituents of the undecomposed material and the specific gravities of two of them (felspar and chromite) are known, it is now possible from the specific gravity of the mixture (§ 14) to calculate the specific gravity of the third constituent (enstatite). The specific gravity of oligoclase Ab_3An_1 is 2·66: that of chromite varies from 4·32 to 4·57 (Dana), the mean of which is 4·44: that of the mixture was found to be 3·171 (§ 14). The total volume of a mixture being the sum of the volumes of the constituents, it follows that, if x be the specific gravity of the enstatite,

$$\frac{78{\cdot}71}{x} + \frac{19{\cdot}84}{2{\cdot}66} + \frac{1{\cdot}45}{4{\cdot}44} = \frac{100}{3{\cdot}171}.$$

Whence x is 3·314.

The specific gravity of the Lodran enstatite was directly determined by Professor Tschermak to be 3·313.

Undecomposed material: Amount of action of hydrochloric acid and sodic solution.

30. The trace of undecomposed material, which, after treatment with hydrofluoric and sulphuric acids, weighed 0·0014 (§ 17), must before that treatment have weighed 0·0017 (§ 19); hence SiO_2 is 0·0746: and the total amount of undecomposed silicate is 0·0017+0·8807+0·0363 or 0·9187; for ignition does not appreciably alter the weight of the undecomposed material (§ 18). After deduction of SiO_2 0·0049 due to the sodic solution itself (§ 13), we have, for the SiO_2 due to the silicate, 0·0697.

For the hydrochloric acid extract:—

Fe_2O_3,Al_2O_3,SiO_2 0·0150 consisted of Fe_2O_3 0·0140 (corresponding to FeO 0·0127), Al_2O_3 0·0009, SiO_2 *nil*.

Deducting 0·0054 from $Mg_2P_2O_7$ 0·0649 as being really $Ca_2P_2O_7$ due to the action of the nitric acid on the porcelain (§ 20), we have $Mg_2P_2O_7$ 0·0595, corresponding to MgO 0·0215. Collecting the results:—

	Acid Extract.	Sodic Extract.	Total Extract.
SiO_2	—	0·0697	0·0697
FeO	0·0127	—	0·0127
MnO	—	—	—
MgO	0·0215	—	0·0215
CaO	0·0076	0·0023	0·0099
Al_2O_3	0·0009	0·0062	0·0071
K_2O / Na_2O	undet.	undet.	undet.
		Total extract	0·1209
		Undecomposed residue	0·9187
		Weight found	1·0396
		Weight taken	1·0388

Hence it follows that when the undecomposed material is subjected to the action of hydrochloric acid and sodic solution in the same way and for the same length of time as in the analysis of the mixed powder itself, no less than 11·64 per cent. pass into the acid or sodic solution. As there is little alumina in the acid extract, either the felspar is only very slightly attacked by the acid, or the alumina is set free in such a form as to be only with difficulty soluble in the acid, though removable by the sodic solution[1]; more probably the greater part of the decomposition of the felspar is due to the sodic solution itself.

If we allow soda in sufficient proportion to form oligoclase with the alumina (§ 24) the percentage composition of the total extract is

SiO_2	56·44
FeO	10·29
MnO	—
MgO	17·41
CaO	8·02
Al_2O_3	5·75
K_2O / Na_2O	2·09
	100·00

The total extract has thus nearly the same composition as the original mixture (§ 23). The chief part of the solvent action on the enstatite is

[1] Jour. Chem. Soc. vol. 41, 1882, Transactions, p. 159.

due to the acid; the silica set free by this action is removed by the sodic solution, which at the same time acts to some extent on the felspar, taking all the constituents into solution, and probably to some extent on the enstatite, removing the silica and lime but leaving its oxide of iron and magnesia in the final residue. The corresponding oxide of iron and magnesia left in the undecomposed residue by the action of the previous sodic solution will have passed into the acid extract.

Unattracted material: Treatment with mercuric solution.

31. Fe_2O_3 0·0021 (§ 9) corresponds to Fe 0·0015. Hence the total amount of alloy extracted by the mercuric solution from 4·9856 grams of the unattracted material was at most 0·0022, containing 31·82 per cent. of nickel; as already stated, the high percentage of the nickel was already manifested by the colour of the extract. This again points to the easy oxidation of the iron of the finer particles of nickel-iron during the exposure to the air in the course of the magnetic separation and afterwards; the nickel being less easily oxidised and less readily attracted by the magnet, the percentage of the nickel in the metallic portion still left with the unattracted material will be higher than in the original nickel-iron.

Unattracted material: Alkalies.

32. K_2PtCl_6 0·0040 (§ 8) corresponds to KCl 0·0012; 0·0036, adherent to the filter and ignited, if taken as Pt·2KCl, corresponds to KCl 0·0016; making altogether KCl 0·0028.

From the blank experiment (§ 22) the KCl due to the reagents is 0·0021; hence only KCl 0·0007 can be assigned to the silicate.

The mixed chlorides due to the silicate weigh 0·0135 (§ 8) − 0·0021 (§ 22), or 0·0114; the NaCl is thus 0·0107.

These amounts of NaCl and KCl correspond respectively to Na_2O 0·0057 and K_2O 0·0004 for 0·4815 of material, and to Na_2O 1·18 and K_2O 0·08 per cent.

As the total amount of matter extracted from the unattracted material by boiling water amounted to only 0·26 per cent. and part of it consisted of calcium and magnesium, it is inferred that the alkalies were present in the unattracted material as constituents of an insoluble compound, presumably felspar.

Unattracted material: First Portion.

33. The trace of undecomposed material which, after treatment with hydrofluoric and sulphuric acids weighed 0·0039 (§ 10), must before that treatment have weighed 0·0047 (§ 19); and the total amount of undecom-

posed material is 0·0047+0·9186+0·1328 or 1·0561, for ignition does not appreciably alter the weight of the undecomposed material (§ 18).

The true SiO_2 is 0·4909−0·0047 or 0·4862: but of this 0·0049 are due to the sodic solution itself (§ 13): the SiO_2 really due to the silicate is thus 0·4813. Of the Fe_2O_3,Al_2O_3,SiO_2 0·0048, the Fe_2O_3 was small and probably only that from the sodic solution itself 0·0009 (§ 13), the SiO_2 was 0·0031 (making the total SiO_2 0·4844) and (by deficit) Al_2O_3 is 0·0008.

The Fe_2O_3,Al_2O_3,SiO_2 0·4639 from the acid extract consists of Fe_2O_3 0·4578 (corresponding to FeO 0·4120), Al_2O_3 0·0040 (and SiO_2 0·0021 due to action on the vessels).

Further 2·5065 of unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1412, which is itself equivalent to FeO 0·1155; as this iron is in the acid extract, only FeO 0·2965 (*i.e.* 0·4120−0·1155) is due to the silicate.

MnS 0·0068 corresponds to MnO 0·0055.

[NiO 0·0001 may be neglected in the calculations.]

Hence we have:—

			Percentages.
Undecomposed material ...	...	1·0561	42·13
Troilite ...	...	0·1412	5·63
SiO_2 ...	...	0·4844	19·33
FeO ...	...	0·2965	11·83
MnO ...	...	0·0055	0·22
MgO ...	...	undet.	undet.
CaO ...	...	undet.	undet.
Acid extract 0·0040 / Sodic extract 0·0008	Al_2O_3 ...	0·0048	0·19
K_2O ...	...	undet.	undet.
Na_2O ...	...	undet.	undet.
	Total	1·9885	79·33
	Weight taken	2·5065	100·00

Unattracted Material: Second Portion.

34. The amount of volatile material corresponding to 2·7333 of the material taken for analysis would be 0·0680 (§ 11), and the weight of the pure material was thus 2·6653.

The trace of undecomposed material which after treatment with hydrofluoric and sulphuric acids weighed 0·0017 (§ 11) must before that treatment have weighed 0·0021 (§ 19): and the total amount of undecomposed material is 0·0021+1·0981+0·0516, or 1·1518, for the weight of the undecomposed material is not appreciably altered by the ignition (§ 18).

The true SiO_2 is thus 0·5296−0·0021 or 0·5275; but of this 0·0049 is due to the sodic solution itself (§ 13); the SiO_2 really due to the silicate being therefore 0·5226.

The Fe_2O_3,Al_2O_3,SiO_2 0·0065 consists of Fe_2O_3 0·0020, Al_2O_3 0·0035 and SiO_2 0·0010 (making the total SiO_2 0·5236): deducting Fe_2O_3 0·0009 as due to the sodic solution itself, Fe_2O_3 0·0011 has passed into the sodic solution from the silicate (possibly through finely divided silicate passing through the pores of the filter).

The Fe_2O_3,Al_2O_3,SiO_2 0·5013 of the acid extract consists of Fe_2O_3 0·4960, Al_2O_3 0·0019 and SiO_2 0·0034 (due to action on the vessels).

(NiS ignited 0·0012 may be omitted in the calculations.)

MnS 0·0074 corresponds to MnO 0·0060.

The $Mg_2P_2O_7$ (pure) is 1·3834 (§ 11) − 0·0054 (§ 20) or 1·3780, corresponding to MgO 0·4989.

The total Fe_2O_3 is 0·4960 + 0·0011 or 0·4971, corresponding to FeO 0·4474: further, 2·6653 of the unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1502, which itself is equivalent to FeO 0·1259: as this iron is in the acid extract, only 0·3215 (*i.e.* 0·4474 − 0·1259) of FeO is due to the silicate.

The total CaO obtained is 0·0013 + 0·0105 or 0·0118; from this must be deducted 0·0005 as due to the sodic solution (§ 13).

Also 2·6653 of the unattracted material contain (§ 22) K_2O 0·0022, Na_2O 0·0315; and the 1·1518 of undecomposed material contain (§ 22) K_2O 0·0021, Na_2O 0·0182: hence there must have passed into the acid and alkaline solutions K_2O 0·0001 (or *nil*) and Na_2O 0·0133.

Collecting the results we have :—

			Percentages.
Undecomposed material ...	1·1518	43·21
Troilite	0·1502	5·64
SiO_2	0·5236	19·65
FeO	0·3215	12·06
MnO	0·0060	0·23
MgO	0·4989	18·72
CaO	0·0113	0·42
Acid extract 0·0019 / Sodic extract 0·0035 Al_2O_3 ...	0·0054	0·20
K_2O	*nil*	*nil*
Na_2O	0·0133	0·50
Total	2·6820	100·63
Weight taken	2·6653	100·00

Unattracted Material: Third Portion.

35. The trace of undecomposed material which, after treatment with hydrofluoric and sulphuric acids weighed 0·0026 (§ 12), must before that treatment have weighed 0·0032 (§ 19); and the total amount of undecomposed material is 0·0032 + 0·8107 + 0·0241, or 0·8380, for the undecomposed material is not appreciably altered in weight by ignition (§ 18).

The true SiO_2 is thus 0·4208 − 0·0032 or 0·4176, but of this 0·0049 is due to the sodic solution itself (§ 13); hence the SiO_2 really due to the silicate is 0·4127.

The Fe_2O_3,Al_2O_3,SiO_2 0·0069 consists of Fe_2O_3 0·0037, Al_2O_3 0·0031 (SiO_2 0·0001, making the total SiO_2 0·4128).

Deducting Fe_2O_3 0·0009 as due to the sodic solution itself, Fe_2O_3 0·0028 has passed into the sodic solution from the silicate (possibly through finely divided silicate passing through the pores of the filter).

The Fe_2O_3,Al_2O_3,SiO_2 0·3775 consists of Fe_2O_3 0·3755, Al_2O_3 0·0002 (SiO_2 0·0018, due to the action on the vessels).

CuS (ignited) 0·0003 and Ni(Co) 0·0010 may be neglected during the calculation.

MnS 0·0056 corresponds to MnO 0·0046.

The $Mg_2P_2O_7$ (pure) is 1·0958 (§ 12) − 0·0054 (§ 20) or 1·0904, corresponding to MgO 0·3948.

The total Fe_2O_3 is 0·3755 + 0·0028 or 0·3783, corresponding to FeO 0·3405; further, 2·0317 of the unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1145 which itself corresponds to FeO 0·0936; as this iron is in the acid solution, only 0·3405 − 0·0936, or 0·2469, of FeO is due to the silicate.

The total CaO obtained is 0·0023 + 0·0107 or 0·0130; from this must be deducted 0·0005 as due to the sodic solution (§ 13).

Also 2·0317 of the unattracted material contain (§ 32) K_2O 0·0017, Na_2O 0·0241; and the 0·8380 of undecomposed material contains (§ 22) K_2O 0·0015, Na_2O 0·0133: hence K_2O 0·0002 (or *nil*) and Na_2O 0·0108 must have passed into the acid and sodic extracts.

Collecting these results we have:—

			Percentages.
Undecomposed material ...	...	0·8380	41·25
Troilite	...	0·1145	5·64
SiO_2	...	0·4128	20·32
FeO	...	0·2469	12·15
MnO	...	0·0046	0·23
MgO	...	0·3948	19·43
Acid extract 0·0107 / Sodic extract 0·0018	CaO ...	0·0125	0·61
Acid extract 0·0002 / Sodic extract 0·0031	Al_2O_3 ...	0·0033	0·16
K_2O	...	*nil*	*nil*
Na_2O	...	0·0108	0·53
	Total	2·0382	100·32
	Weight taken	2·0317	100·00

36. Bringing the results together for convenience of comparison, we have:—

	I.	II.	III.	Mean.	Oxygen.	
Undecomposed material	42·13	43·21	41·25	42·20	—	
[Troilite ...	5·63	5·64	5·64	5·64]	—	
SiO_2	19·33	19·65	20·32	19·77	10·47	
FeO	11·83	12·06	12·15	12·01	2·67	10·46
MnO... ...	0·22	0·23	0·23	0·23	0·05	
MgO... ...	undet.	18·72	19·43	19·07	7·59	
CaO	undet.	0·42	0·61	0·51	0·15	
Al_2O_3 ...	0·19	0·20	0·16	0·18	0·08	
[Na_2O... ...	undet.	0·50	0·53	0·51]	0·13	
Total	79·33	100·63	100·32	100·12		
Weight taken	100·00	100·00	100·00	100·00		

In the analysis of the first portion, the three successive extractions with acid were allowed to proceed for $1\frac{1}{2}$ hours, 2 hours and 2 hours, respectively; in the case of the second portion the times were 2 hours, $1\frac{3}{4}$ hours, and 2 hours, respectively; in that of the third portion, each extraction lasted two hours. As it has been shown (§ 30) that no less than 11·64 per cent. of the undecomposed material are decomposed during such extractions, it follows that the variation from 41·25 per cent. to 43·21 per cent. in the amount of residue in the three analyses is sufficiently accounted for by variations of circumstances during the extractions; for instance, of the times for which each extraction is allowed to proceed, the temperature of the extracting acid, the frequency of renewal of the evaporated water, and so on. The actual extract corresponds very closely to olivine, and neglecting the soda and alumina has the following composition:—

		Per cent.	Oxygen.		Muddoor.	Linn County.
SiO_2	19·77	38·25	20·26		38·32	38·80
FeO	12·01	23·23	5·16		23·29	21·31
MnO	0·23	0·45	0·10	20·28	—	—
MgO	19·07	36·89	14·68		36·90	39·89
CaO	0·51	1·18	0·34		1·07	—
				Al_2O_3	0·42	—
	51·59	100·00			100·00	100·00

This composition is virtually identical with that calculated by Crook[1] for the olivine of the Muddoor meteorite and also is very nearly that of the "decomposed portion" of the Linn County stone as analysed by Rammelsberg[2].

Some of the silica, however, must have been originally in combination with the soda and alumina which have been neglected, and further a small quantity of the remaining constituents is due to the action of the hydrochloric acid and sodic solution on the enstatitic silicate.

37. An estimate of the quantities due to the action on the refractory silicates can be obtained by assuming that they are in the same proportion to the undecomposed residue as in the analysis mentioned in § 30. But the estimate will be only approximate, for in the analysis of the mixture the strength of the acid and its decomposing effect are diminished owing to the action of the olivine: further the gelatinous silica from the olivine will partially protect the other silicates from the acid; and the presence of the compounds due to the decomposition of the olivine may have a disturbing effect on the action of the acid.

These considerations being disregarded, it follows from § 30 that when the residue weighs 88·36 the following amounts due to the refractory silicates have passed into solution:—SiO_2 6·57, FeO 1·20, MgO 2·03, CaO 0·93, Al_2O_3 0·67, R_2O 0·24; hence for the residue 42·20 the corresponding amounts are SiO_2 3·14, FeO 0·57, MgO 0·97, CaO 0·44, Al_2O_3 0·32, R_2O 0·11, making in all 5·55. Deducting these amounts from the quantities found in the solution (§ 36), we have for the less refractory silicate itself:—

SiO_2 16·63, FeO 11·44, MnO 0·23, MgO 18·10, CaO 0·07, Al_2O_3 −0·14, Na_2O 0·40.

Omitting the CaO, Na_2O, Al_2O_3 as being possibly extraneous, we have the following composition:—

		Per cent.	Oxygen.			Muddoor (observed).
SiO_2	16·63	35·84	18·98		SiO_2	35·46
FeO	11·44	24·65	5·48	21·11	FeO	24·36
MnO	0·23	0·50	0·11			
MgO	18·10	39·01	15·52		MgO	38·61
					CaO	1·13
					Al_2O_3	0·44
	46·40	100·00				100·00

[1] Die Chemische Natur der Meteoriten, von C. Rammelsberg, 1879, p. 54.

[2] Monatsb. Ak. Wiss. Berlin, 1870, p. 459.

The nearness of the oxygen-ratio to that of olivine is thus lessened by the deduction of the quantities resulting from the action on the refractory silicates; but the composition is almost identical with that observed by Crook for the decomposable silicate of the Muddoor meteorite.

According to this interpretation, the total amount of enstatite, felspar and chromite in the unattracted material would be 47·75 per cent., 42·20 per cent. remaining undecomposed and 5·55 per cent. passing into the acid and sodic solution.

Unattracted Material: Chromite.

38. Since the unattracted material yields 42·20 per cent. of undecomposed residue (§ 36) and the latter itself contains (§ 28) 1·45 per cent. of chromite, the unattracted material must contain 0·61 per cent. of chromite. By direct extraction with hydrofluoric and sulphuric acids only 0·35 per cent. was isolated, but probably some is decomposed and passes into solution (§ 6). Similarly, the chromium obtained during the determination of the alkalies corresponds to only a small fraction of the total chromite.[1]

39. The enstatite and oligoclase of the unattracted material will thus (§§ 37, 38) amount to (47·75 − 0·61 or) 47·14 per cent., and this will consist (§ 28) of 37·65 of enstatite and 9·49 of oligoclase; the troilite is 5·64 per cent. (§ 36): hence the olivine amounts to 46·61 per cent. The mineral composition of the unattracted material (neglecting minute quantities of nickel-iron and schreibersite) will therefore be

			Total weight.
Olivine	...	46·61	5·7894
Enstatite	...	37·65	4·6764
Oligoclase	...	9·49	1·1787
Troilite	...	5·64	0·7005
Chromite	...	0·61	0·0758
		100·00	12·4208 grams.

Attracted Material: First Set of Extracts.

40. The Fe_2O_3,P_2O_5,SiO_2 0·4933 (§ 2) consists of Fe_2O_3 0·4895 (corresponding to Fe 0·3427), P_2O_5 0·0003 (corresponding to P 0·0001), (SiO_2 0·0028 due to the action on the vessels).

The phosphorus being present as Fe_2NiP (schreibersite) requires Fe 0·0004, Ni 0·0002.

The Ni(Co) due to nickel-iron (§ 2) is thus 0·0487 − 0·0002 or 0·0485.

[1] Mineralogical Magazine, 1894, vol. 10, p. 307.

Hence we have :—

Extracted :—Nickel-iron	Fe	0·0342	0·3908
	Ni(Co)	0·0485	
Schreibersite	...	...	0·0007
Residue (§ 3)	...	...	0·3385
		Total	0·7300
		Weight taken	0·7421

No great stress can be laid on the loss of weight (0·0121), owing to the character of the necessary operations.

The percentage composition of the nickel-iron (0·3908) which has passed into solution is Fe 87·59, Ni(Co) 12·41.

Further, $3K_2SO_4.2CoSO_4$ 0·0166 corresponds to Co 0·0024 : hence the percentage composition of the Ni(Co) is Ni 95·07, Co 4·93, and that of the nickel-iron is Fe 87·59, Ni 11·80, Co 0·61, Cu *trace*.

Attracted Material : Second Set of Extracts.

41. Fe_2O_3 0·0439 (§ 3) corresponds to Fe 0·0307 ; and the Ni(Co) is 0·0135.

Hence we have :—

Extracted :—Nickel-iron	Fe	0·0307	0·0442
	Ni(Co)	0·0135	
Residue (§ 4)	...	...	0·2850
		Total	0·3292
		Weight taken	0·3366

As before, no stress can be laid on the loss of weight (0·0074) ; the percentage composition of the nickel-iron (0·0442) extracted in the second series of operations is Fe 69·46, Ni(Co) 30·54.

Attracted Material : Residue.

42. The Fe_2O_3,SiO_2 0·0450 (§ 4) consists of Fe_2O_3 0·0447 (corresponding to Fe 0·0306) and SiO_2 0·0013 (due to the action on the vessels).

$Mg_2P_2O_7$ 0·1137 corresponds to MgO 0·0412 (having regard to the smallness of this amount, the action of the nitric acid on the vessels must likewise have been small, and no deduction is made) ; the MgO being due to the silicates, other constituents in corresponding proportion must likewise be due thereto ; hence the quantities will be (§ 35) :—

SiO_2 0·0420, MgO 0·0412, FeO 0·0245, MnO 0·0005, CaO 0·0011, making altogether 0·1093 of silicate decomposed by the hydrochloric acid ; this leaves SiO_2 0·0027 (namely 0·0447 − 0·0420) unallotted ; the above quantities are only approximate, for the enstatitic and felspathic

silicates are acted on by the acid and sodic solutions, and their proportions to the olivine are probably different from those which obtain in the unattracted material. Further, FeO 0·0245 of the silicate corresponds to Fe 0·0191 which is included in the above total Fe 0·0306; the Fe due to the alloy itself is thus 0·0115.

Hence we have :—

Final residue (enstatite, &c.) ...	0·1409 (§ 4)
Silicate decomposed (olivine, &c.) ...	0·1093
Fe	0·0115
Ni(Co)	0·0072
Unallotted SiO_2	0·0027
Total	0·2716
Weight taken	0·2757

The loss in this case (0·0041) is, partly at least, oxygen : the amount of oxygen necessary to convert the whole of the iron into Fe_3O_4 would be 0·0044. That there is a certain amount of unoxidised metal present is shown by the effervescence of the material with the acid (§ 4) : that there is oxide present is indicated by the extreme slowness of action of the mercuric solution on the material (§ 3). As there is only a small proportion of black opaque matter visible in the thin sections when examined with the microscope, and this is probably chromite, the oxidation had probably taken place during the analysis itself, as already suggested (§ 2). The iron and nickel in this residue corresponding to original metal will thus be Fe 0·0115, Ni(Co) 0·0072, corresponding to 0·0187 of alloy having the percentage composition Fe 61·50, Ni(Co) 38·50.

43. Hence we have the following results :—

	Nickel-iron.	Fe.	Ni(Co).	Percentage of Ni(Co).
First Extracts ...	0·3908	0·3423	0·0485	12·41
Second Extracts ...	0·0442	0·0307	0·0135	30·54
Residue	0·0187	0·0115	0·0072	38·50

Hence, of the total nickel-iron contained in the attracted material, 86·13 per cent. are removed in the first set of extractions, 9·75 in the second, and the remaining 4·12 is left partly as oxide and partly as metal, the latter protected from the mercuric solution by enclosing oxide or silicate. The variation of the percentage of nickel (cobalt) from 12·41 to 38·50, as the extraction proceeds, does not necessarily imply the existence of different alloys of nickel-iron in the material; it is probably a

mere result of the easier oxidation of the iron than the nickel during exposure of the alloy to the atmosphere in the course of the operations.

Attracted Material: Mineral Composition.

44. Calculation, from these numbers, of the composition of the various residues leads to the following composition for the attracted material:—

	Grams.
Nickel-iron	1·2422
Olivine	0·3373
Enstatite	0·3474
Oligoclase	0·0875
	2·0144;

for the proportion of the decomposed to the undecomposed silicate is known from § 42, and the proportion of the enstatite to the oligoclase may be taken to be the same as for the previous similar material (§ 28).

Mineral Composition of the Fragment.

45. From §§ 39, 44, the mineral composition of the complete fragment was:—

	Grams.	Zomba. Percentages.	Linn County.[1] Percentages.
Nickel-iron ...	1·2422	8·61	10·54
Olivine ...	6·1267	42·44	41·85
Enstatite ...	5·0238	34·80	41·24
Oligoclase ...	1·2662	8·77	
Troilite ...	0·7005	4·85	6·37
Chromite ...	0·0758	0·53	—
	14·4352	100·00	100·00

Mineralogical Relationship to other Meteoric Stones.

The Zomba meteorite thus consists of a stony material composed of olivine and enstatite in nearly equal quantity admixed with a certain amount of oligoclase; embedded in this stony material are nickel-iron and troilite in considerable quantity and small amounts of chromite and schreibersite. In the aspect of the thin sections as seen under the microscope, in the proportions of the mineral constituents (§ 45), in the percentage chemical composition of the silicate decomposed by hydrochloric acid (§ 36) and in that of the silicate obtained as a residue after the action of the acid and the sodic solution (§ 23), the Zomba meteorite

[1] Monatsb. Ak. Wiss. Berlin, 1870, p. 458.

closely resembles the stone which fell in Linn County, Iowa, U.S.A., on 25th February, 1847; different parts of one meteoric stone would generally show greater differences. The composition here assigned to the Zomba enstatite, after analysis of what is interpreted to be a mixture of enstatite and oligoclase, is very near to that found by Professor Tschermak for the coarse grains of enstatite which he was able to isolate from the Lodran stone for chemical determination (§ 27), and the specific gravity as calculated for the Zomba enstatite from the specific gravity of the mixture is virtually identical with the specific gravity directly determined by Professor Tschermak for the isolated Lodran mineral (§ 29). Further, it is found that the "undecomposed residue," when itself subjected to the treatment used in the analysis of the unattracted material, loses nearly 12 per cent. of its weight; the enstatite is chiefly acted upon by the acid, the oligoclase by the sodic solution (§ 30).

Marshite, Miersite and Iodyrite from Broken Hill, New South Wales.

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[Read April 5th, 1898.]

MINERALS containing iodine as an essential constituent are of rare occurrence in nature. The most common, and that first described, is silver iodide, which was analysed by Vauquelin in 1825; hexagonal crystals of iodyrite were described by Des Cloizeaux in 1854. Other iodides are marshite and the new mineral miersite; iodobromite and schwartzembergite also contain considerable amounts of iodine. The existence of mercury iodide seems to be doubtful; the supposed mercury iodide from Broken Hill consists of an intimate mixture of cinnabar and iodyrite.[1] Two iodates are also known, namely lautarite and dietzeite.

I. Marshite.

Crystals of "native copper iodide" were discovered at Broken Hill, New South Wales, by C. W. Marsh,[2] in 1892. The results of his qualitative analysis showed the presence of copper and iodine, and the crystallographic form was stated to be "tetragonal-hemihedral." In an abstract of this paper Prof. Miers[3] pointed out with reference to the statement of the crystalline form: "hier ist wohl ein Fehler, denn Krystalle von derselben Substanz, die im britischen Museum sich befinden, sind tetraëdrisch und gehören dem regulären Systeme an."

It is possible that Marsh made his crystallographic observations on either wulfenite or stolzite, both of which minerals have several times

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[1] Silver iodide is extracted when the substance is digested with a solution of potassium iodide. See also J. B. Jaquet, "Geology of the Broken Hill Lode and Barrier Ranges Mineral Field, New South Wales," Memoirs Geol. Survey, N.S.W., 1894, Geol. Ser. No. 5, p. 90.

[2] Journal and Proc. Roy. Soc. New South Wales, for 1892 [1893], XXVI. 326 (Abstract Min. Mag. XI. 236). The principal characters of the mineral were verified by Prof. A. Liversidge, who in an accompanying note (p. 328) proposed the name marshite. A later brief description of the mineral is given by G. W. Card, Records Geol. Survey, N.S.W. 1895, IV, 131.

[3] Zeits. Kryst. Min. 1894, XXIV. 207.

been sent to the British Museum labelled as marshite. The crystal of marshite measured by Prof. Miers was isotropic; it was bounded by faces of the cube and of two tetrahedra, and was twinned on a tetrahedron face.

Tetrahedral crystals of cuprous iodide have been prepared by E. Meusel[1] by the action of hydriodic acid on metallic copper or on copper-glance. Although a quantitative analysis has not been made of marshite, it is without doubt identical with this artificial cuprous iodide.

Occurrence: *Physical Characters.*—The description of the mineral to be now given is based on an examination of seven specimens in the British Museum collection, all of which are from Broken Hill. Labels with three of the specimens give the exact locality as the Broken Hill Proprietary Consols Mine.

The crystals of marshite are usually scattered over the surface of platy or cellular psilomelane, which in turn encrusts an incoherent mixture of limonite and cerussite[2] with grains of quartz and grains and dodecahedra of brown garnet. Sometimes copper-glance or cuprite is also present, the latter in good crystals altered on the surface to malachite. On one specimen the psilomelane forms a thin coating on blue opalescent quartz. The matrix of another specimen consists of massive and crystallised cuprite, with some native copper, quartz and brown garnet.

The faces of the crystals are bright and have a resinous to adamantine lustre. The colour varies from very faint yellow to dark brick-red, but the streak is always bright lemon-yellow. For an almost colourless crystal to give a bright yellow streak is very striking. Exposure to bright sunlight for several days does not affect the colour. Only the very pale coloured crystals are transparent, the others varying from translucent to almost opaque according to the depth of colour.

An important character not before noticed is the perfect dodecahedral cleavage, $d\{110\}$. The fracture is conchoidal, and the mineral is rather brittle; hardness $2\frac{1}{2}$ on Mohs' scale.

The crystals and cleavage flakes are as a rule optically isotropic, but sometimes a broken crystal shows uneven extinction, as if strained. The refractive index was approximately[3] determined for light of different colours with a colourless transparent prism of which the refracting

[1] Ber. deutsch. chem. Ges. 1870, III. 123.

[2] The cerussite shows stellated groups with twin-plane $m(110)$. A measured crystal was twinned on $r(130)$, and agreed closely with Mügge's description of cerussite from Broken Hill (Neues Jahrb. Min. 1897, II, 78).

[3] The images were somewhat scattered.

angle of 35° 13½′ (calculated 35° 16′) was formed by a tetrahedron face and a dodecahedral cleavage.

$$n_{(Li)}=2{\cdot}313,\ n_{(Na)}=2{\cdot}346,\ n(Tl)=2{\cdot}385.$$

For the extreme visible ends of the spectrum of white light the refractive indices are approximately 2·25 and 2·7. The dispersion is thus considerably higher than in diamond.

Crystallographic Characters.—Two types of the marshite crystals are to be distinguished; they may occur separately or together on the same specimen. On one specimen the crystals of type *A* pass into a continuous crust of ash-grey marshite, on which the larger and darker coloured crystals of type *B* are deposited. The crystals of the two types therefore appear to belong to two different periods of growth.

Type A.—Bright crystals usually scattered singly over the matrix; they are of minute size, but on one specimen measure 1·5 mm. across. The colour is usually pale wine-yellow, but varies from almost colourless to brighter yellow. Faces of the cube and of both tetrahedra are prominently developed (compare Fig. 1, p. 46), and some of the crystals are cubo-octahedral in habit.

Type B.—Crystals of this type are larger and average 1—1·5 mm. across. They vary in colour from orange-red to brick-red. The habit is distinctly tetrahedral, owing to the small development or absence of one tetrahedron, and of the cube. The crystals are often grouped together in parallel position.

Although a dozen crystals (of both types) were measured on the goniometer, the only forms noticed were the cube $a\{100\}$ and the two tetrahedra $+o\{111\}$ and $-o\{1\bar{1}1\}$. The measurements were usually good, and agreed closely with the calculated angles of cubic crystals.

The faces of both tetrahedra are bright and smooth; they show no difference in character, and on some crystals of type *A* they are of equal size. The cube faces are slightly striated parallel to their intersection with either the larger or the smaller tetrahedron faces. On crystals of type *B* the faces of the large tetrahedron are often striated and stepped parallel to their intersections with the cube faces, the edges of the steps being usually bounded by narrow planes in twin position relative to the main crystal. Juxtaposed twins with a tetrahedron face as twin-plane are frequent, and angles of 15°48′ ($=oa$) were often measured. Some crystals are twinned on more than one tetrahedron face.

The characters described above are remarkably like those of zinc-blende, and the refractive index is also nearly the same; the crystallographic

characters—habit, twinning and cleavage—are identical, and in fact some of the crystals, especially those of type *A*, are very similar in appearance to the crystals of yellow zinc-blende from the white dolomite of the Binnenthal in Switzerland, the figures of which given by Sadebeck and vom Rath may very well be taken to represent marshite.

Chemical Characters: Behaviour when heated.—Qualitative chemical tests made on crystals from two specimens showed the presence of only copper and iodine. These crystals, and also those from other specimens with one exception, when placed in a drop of cold dilute nitric acid, are quickly blackened on the surface owing to the liberation of iodine, and they are not reduced by zinc and sulphuric acid. Crystals from one specimen (of which the matrix is blue opalescent quartz) were found to contain a small amount of silver; these crystals are not blackened in cold dilute nitric acid, and they are reduced by zinc and sulphuric acid; they thus behave with these reagents like miersite (p. 42) and not like pure marshite (CuI.)

When heated on a microscope slide, the crystals become dark red and decrepitate; on cooling they regain their original colour. At a higher temperature the pure crystals blacken and decompose without fusing; but those which contain silver sometimes fuse to a reddish liquid, which on cooling solidifies to an aggregate of isotropic grains.

II. Miersite.

A preliminary account of miersite, named in honour of Dr. Henry A. Miers, F.R.S., Professor of Mineralogy in the University of Oxford, was given in *Nature*[1] for April 14th, 1898. A more detailed account has been deferred in the hope that sufficient material would be available for a quantitative chemical analysis. Six specimens of the mineral have now been found for the British Museum collection, but it would not be advisable to collect material for analysis from more than one, since the amount of copper varies in the different specimens.

Occurrence: Physical Characters.—All the specimens are from Broken Hill, New South Wales. The associated minerals are cerussite, limonite, malachite, brown garnet, and quartz, with sometimes copper-glance and cuprite which have escaped alteration. The miersite occurs on the free surface of the specimens, usually as crystalline crusts or as aggregates of rather indistinct crystals. Distinctly developed crystals are less frequent

[1] "Miersite, a cubic modification of native silver iodide." By L. J. Spencer. Nature, 1898, LVII, 574. The minute crystals on one of the specimens there mentioned have since been shown to belong to type *b* of iodyrite (see p. 46 below).

than in marshite. The crystals are sometimes about 2 mm. across, but usually they are much smaller.

The colour of the crystals and of the streak is canary-yellow, and it is not affected by exposure for several days to bright sunlight. The crystals are translucent, and have a resinous to adamantine lustre. The mineral is somewhat brittle, and has a hardness of $2\frac{1}{2}$: a crystal when crushed breaks into angular fragments without any distortion of the faces, and by this miersite is at once distinguished from iodyrite. The fracture is conchoidal, and there are, as in marshite, perfect cleavages parallel to the faces of the rhombic-dodecahedron, $d\{110\}$. Small fragments and cleavage flakes are transparent and, as a rule, perfectly isotropic.

Crystallographic Characters.—The crystallographic characters of miersite are exactly similar to those of marshite and zinc-blende. The habit varies from tetrahedral with narrow cube planes (compare Fig. 1, p. 46) to cubo-octahedral. Usually both tetrahedra are present and of different sizes, but they show no difference in surface characters. The crystals are frequently twinned, and this twinning may be more than once repeated, and on more than one tetrahedron face: as a result of this the angle $oa = 15°48'$ is of frequent occurrence. The faces are bright and smooth; those of the cube are sometimes striated parallel to the intersection with either the larger or the smaller tetrahedral faces. Tetrahedral faces show triangular striations and elevations, the edges of which are usually bounded by narrow planes in twin position relative to the main crystal. Although detailed measurements were made of more than a dozen crystals, these were the only forms noted. As a rule the measured angles only differed by a few minutes from the calculated cubic angles.

The habit of one of the measured crystals is that of a hemimorphic rhombohedral crystal of iodyrite with the forms $y\{55\bar{4}\}$ and $c\{111\}$. The planes prominently developed are three cube faces ($\bar{1}00$, $0\bar{1}0$, $00\bar{1}$), and one tetrahedron face (111), which is also the plane of twinning. On this crystal the perfect dodecahedral cleavage was purposely developed in five directions, and the cleavage flakes detached were perfectly isotropic. No pyroelectricity was detected on this, or any other crystal, by dusting a cooling crystal with red-lead and sulphur.

Chemical Characters: Behaviour when heated.—Qualitative chemical tests showed the presence of much silver and iodine, with varying amounts of copper. A very little chlorine may also be possibly present in some crystals. The mineral is not affected by dilute nitric acid, but is readily reduced by zinc and sulphuric acid. It is still hoped that sufficient material may be collected for a quantitative analysis.

The optical behaviour of the material after fusion, as described below, gives an approximate idea of the relative proportions of silver iodide and copper iodide. In these experiments only small amounts of material need be used, and comparative experiments can be made on mixtures of artificially prepared silver iodide and copper iodide in known proportions.

Fragments when heated on a microscope slide exhibit a more or less gradual change in colour, passing through bright orange-yellow to brick-red. There is no change in the transparency and isotropic character of the crystals either when hot or when cold. When heated to a higher temperature the crystals fuse to a deep-red liquid which spreads out as a film under the cover-glass. On solidification the substance is reddish-yellow and optically isotropic, and appears to be perfectly homogeneous. As further cooling takes place the colour gradually changes to bright-yellow, when all at once isotropic pale yellow needles commence to grow and branch out at numerous isolated points all over the field of view. These grow rapidly at the expense of the bright yellow substance, until the whole field is occupied by an intergrowth of two isotropic substances with sharp lines of demarcation between them. A little later the remaining bright yellow substance suddenly changes to very pale yellow birefringent iodyrite. This second change in state is the same as that which takes place with pure silver iodide (p. 49), and the sharp line separating the two modifications may be seen to sweep across the field of view from one side to the other; it does not, as in the first change of state, start independently from numerous isolated points.

The slide now, and when cooled to the ordinary temperature, shows an intergrowth of two substances: one isotropic and pale yellow, the other birefringent and paler in colour. The first usually forms a network of rods at angles of $70° - 75°$ or sometimes of nearly 90°, the interspaces of which are occupied by strips of the birefringent material; the latter extinguish parallel to their length and are opposed to quartz in the same direction. The relative amounts of these two substances varies considerably for different crystals; usually there is little or none of the birefringent iodyrite, while for crystals to be described later (p. 44) the isotropic substance is subordinate.

When weighed amounts of precipitated silver iodide and copper iodide in various molecular proportions[1] from AgI+CuI to 8AgI+CuI were

[1] G. F. Rodwell has determined the sp. gr., melting points and coefficients of expansion and contraction of such mixtures, Proc. Roy. Soc. 1881, XXXIII, 143; Phil. Trans. 1883 (1882), CLXXIII, 1154, Plate 96; and M. Bellati and R. Romanese, from their determinations of specific heat and heat of transformation, conclude that molecular compounds are formed by silver iodide and copper iodide. Proc. Roy. Soc. 1882, XXXIV, 104; Phil. Trans. 1883 (1882), CLXXIII, 1169.

intimately mixed and fused on a microscope slide, the same phenomena were observed as with the natural crystals. The mixture 4AgI+CuI gave a slide showing the isotropic network with only a speck here and there of birefringent iodyrite. When more copper iodide was present the whole slide remained isotropic, while with more silver iodide more of the birefringent substance was formed.

The growth of the pale yellow isotropic crystals in the bright yellow isotropic substance is perhaps scarcely a simple change in state from an amorphous (or possibly cubic) modification to a cubic modification, since the crystals appear to have a definite composition (probably 4AgI.CuI), and the residue left after their growth consists of pure silver iodide. If this be the case, then during crystallisation there must be a migration of silver iodide through the solid material. It is, however, of course possible, that on the solidification of the material, two cubic substances, 4AgI.CuI and AgI, are formed, and that each of these undergoes independently a change in state as the temperature falls first to one and then to another definite point.

Intergrowth with Iodyrite.—Crystals from two of the specimens differ considerably from those described above. They have the hardness and cleavage of miersite, but are paler in colour, and are doubly refracting. As a rule they are repeatedly twinned on two faces of the tetrahedron, and the prominent zone containing these two bright tetrahedral faces is deeply furrowed and striated. When viewed in polarised light across this striated zone, the crystals extinguish parallel to the zone-axis, and are opposed to quartz in the same direction. Cleavage flakes perpendicular to this zone-axis are seen, when viewed in parallel polarised light, to consist of three portions, which extinguish at angles of 60° to each other; each portion shows a very finely striated appearance (suggesting the intergrowth of two substances), extinction taking place parallel to the striations. Only rarely could portions of a positive uniaxial figure be distinguished. The refractive index was determined with a prism (bounded by *a* and *c* cleavage) from one of these crystals to be about $2\frac{1}{4}$ for the yellow part of the spectrum. Qualitative chemical tests showed the presence of silver and iodine with only a very small amount of copper; and fragments fused on a microscope slide show only a few of the isotropic bars. These crystals, therefore, appear to consist of an intimate and regular intergrowth of miersite and iodyrite. The nature of this intergrowth is suggested by the iodyrite crystals of type (*b*) (Fig. 1) described below.

Summarising the above observations, miersite may be defined as an optically isotropic, tetrahedral-cubic mineral, of which the composition is

)bably 4AgI.CuI, and which mixes isomorphously with marshite (CuI) the one hand, and on the other forms intimate intergrowths with dyrite.

Possible identities.—When isomorphously mixed with a certain amount marshite, the composition would become identical with that of "cupro-largyrite" (AgI.CuI). This mineral, from Iquique in Chili, is stated[1] be brighter in colour and lustre, and to be harder and less sectile than dyrite; the fracture is given as sub-conchoidal to splintery. These aracters, so far as they go, agree better with those of miersite than with ose of iodyrite, and it seems probable that "cuproiodargyrite" is inter-ediate between miersite and marshite, and not, as the name[2] suggests, cupriferous variety of iodyrite.

Another mineral which may be mentioned here is the silver iodide from ili, examined by Lawrence Smith.[3] His two analyses of "an exceedingly re specimen" showed the presence of traces of copper and chlorine; d he states: "One specimen that I saw had crystalline faces, indicative the rhombic dodecahedron." It is therefore possible that the material he amined may have been iodyrite intergrown with miersite. The silver lide described by Domeyko[4] also seemed to differ from iodyrite in ing brittle and in sometimes giving "cleavage fragments with ombohedral forms."

III. Iodyrite.

Occurrence: Physical Characters.—The occurrence of iodyrite at Broken ill is well known, but as yet no crystallographic description has been ven. The several specimens from this locality in the British Museum llection show two distinct modes of occurrence:

(1) Pale sulphur-yellow crystallised material on a free surface often nsisting of limonite or psilomelane; associated minerals are brown rnets, blue opalescent quartz, malachite, cerussite, cuprite, pyromorphite, glesite, calamine ($ZnCO_3$), chessylite, or wad.

(2) Films or thin layers, of a rather brighter colour, on the surfaces of ckensides in white kaolin. They often show green stains, but the pure aterial free from these stains contains no copper.

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[1] H. Schulze, Chemiker-Zeitung, 1892, XVI, 1952.

[2] Names of a similar construction are, however, frequently admitted into mineralogical nomenclature as species rather than as variety names, e.g. barytocalcite, plumbobismutite, galenobismutite, arsenopyrite, etc.

[3] Amer. Journ. Sci. 1854 [ii.] XVIII, p. 374; U. S. Naval Astronomical Expedition to the Southern Hemisphere (1849-52), Vol. II, 1855, p. 96.

[4] Annales des Mines, 1844, [iv], VI, p. 158.

The mineral is very soft (H about 1, or perhaps less) and sectile, so much so that the crystals can scarcely be touched without suffering distortion. The fracture is conchoidal, and the perfect basal cleavage shows a pearly lustre. Sometimes in freshly opened cavities the crystals are perfectly colourless and transparent with an adamantine lustre; they then somewhat resemble crystals of anglesite in appearance. On exposure to light the colourless crystals very soon assume the usual pale sulphur-yellow colour of iodyrite, and this is not further altered by prolonged exposure to bright sunlight. The streak is rather brighter yellow in colour with a tinge of green; it is shining and easily flakes off the paper.

Optically the mineral is uniaxial, with low positive double refraction. The tabular crystals and cleavage flakes, being so easily bent, usually show undulose extinction in parallel light, and in convergent light the optic figure is often distorted, sometimes resembling a biaxial figure; as a cleavage flake is moved about on the microscope stage the interference figure continually varies. Attempts to produce corrosion and percussion figures on the cleavage flakes were unsuccessful, and on none of the crystals could any pyroelectrical effects be detected.

The physical characters of iodyrite are considerably modified by the presence of a small amount of copper iodide: as explained above (p. 44) this copper may be assumed to be present as 4AgI.CuI (miersite) occurring as an intimate intergrowth with the iodyrite.

Crystallographic characters.—Several crystals were measured on the goniometer, but no reliable determinations of the angles could be made, as few faces are developed, and the crystals are so easily distorted. The crystals are of two distinct types:

(*a*) Hexagonal plates or short prisms, with the forms $c\{111\}$ $m\{2\bar{1}\bar{1}\}$, and sometimes a narrow hexagonal pyramid near the position of $i\{5\bar{1}\bar{1}, \bar{1}11\} = 2P$, if placed as a pyramid of the first order. The prism and pyramid faces are usually striated horizontally. On one specimen the prisms are 1½ cms. in diameter. On none of these crystals was a hemimorphic development observed.

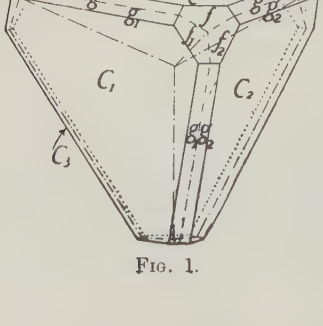

Fig. 1.

(*b*) Pseudo-cubic crystals, of tetrahedral habit, consisting of four simple rhombohedral crystals twinned together. Fig. 1 shows a compound crystal, and Fig. 2 the uppermost of the four simple crystals drawn in parallel position. These crystals cannot be distinguished by gonio

metric measurement from marshite and miersite: they are in fact mimetic crystals of iodyrite with the same external form as miersite and marshite.

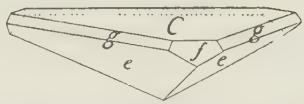

Fig. 2.

The twin-plane $e\{10.1.1\}$[1] $=\frac{3}{4}R$, is the same as that given by vom Rath[2] in his description of iodyrite crystals from New Mexico. He mentioned that three individuals were often arranged around a central one, but in these crystals, since the predominating form was $i\{\bar{1}11\} = -2R$, the twinning was rendered evident by the presence of re-entrant angles. In the crystals now described, $c\{111\}$ predominates in the compound crystal and corresponds to the regular tetrahedron. The smaller faces of $g\{55\bar{4}\} = -\frac{3}{2}R$ and $f\{7\bar{2}\bar{2}\} = 3R$ correspond to the faces of the cube and the second tetrahedron respectively, two faces of g and three of f coming together. These compound crystals therefore show no re-entrant angles.

The angles measured on these pseudo-cubic crystals were not really good, but they agreed closely with the angles of cubic crystals. It is to be noted that the angles determined by von Zepharovich on artificial crystals of iodyrite vary slightly in one direction from cubic angles, while the measurements of Des Cloizeaux and of Seligmann[3] on natural crystals vary slightly on the other side of cubic angles; this is shown in the table below:

	Seligmann.	Cubic angles.	Zepharovich.
$c : e\{10.1.1\} = \frac{3}{4}R$	35°14′	$od =$ 35°16′	35°22′
$c : g\{55\bar{4}\} = -\frac{3}{2}R$	54°42′	$oa =$ 54°44′	54°50′
$c : f\{7\bar{2}\bar{2}\} = 3R$	70°30½′	$oo =$ 70°32′	70°36′
$c : c_1$	109°32′	$oo =$ 109°28′	109°16′
$g : g_1$	Salient 8′	0°	Re-entrant 24′

The compound nature of the crystals is very well shown by the examination in polarised light of cleavage flakes taken parallel to the faces of the pseudo-tetrahedron. In parallel light these show a dark equilateral triangle surrounded by narrow areas extinguishing parallel to the sides of the triangle and opposed to quartz in the same direction. In convergent

[1] The indices are much simplified if g be taken as $(100) = R$; the twin-plane then becomes (110).

[2] F. A. Genth and G. vom Rath, Zeits. Kryst, Min., 1885, X, 473.

[3] Zeits. Kryst. Min. 1882, VI, 229.

light the triangular portion shows in the centre of the field the usual positive uniaxial figure of iodyrite, while the borders show uniaxial brushes belonging to an axis outside the field of view. Usually, however, this structure is polysynthetic, and the same fragment may show, in parallel polarised light, several dark triangular areas and numerous lamellæ in three sets, each set of which extinguish together throughout the whole fragment.

These compound crystals of iodyrite are further twinned on a face, or sometimes on two faces, of the pseudo-tetrahedron, exactly like the crystals of marshite and miersite. As a consequence of this, re-entrant angles of about 15°48′ ($=o\underline{a}$)[1] are frequent, and the narrow faces corresponding to the cube are deeply furrowed and striated. On account of this deep striation it was not possible to determine whether the very small angle gg_1 (Fig. 1) is re-entrant or salient, and thus to decide whether the angles of Zepharovich or of Seligmann come nearer the truth.[2]

The pseudo-cubic crystals of iodyrite of type (*b*) differ essentially from the pseudo-cubic crystals of stannite described in this number of the Magazine (p. 56); these also are twinned on a pseudo-tetrahedron face. The iodyrite crystals were originally true cubic crystals, but are now paramorphs of iodyrite after the tetrahedral-cubic modification of silver iodide. Here the twinning is the result of the pseudo-cubic symmetry, whereas in stannite the twinning is clearly the cause of the pseudo-cubic symmetry. The case of iodyrite is similar to that of many cubic minerals showing optical anomalies which disappear at a higher temperature, *e.g.* boracite, leucite, cristobalite, etc. In the case of iodyrite, however, the two kinds of crystals are known to occur independently. The iodyrite crystals of type (*a*) must have been formed at a temperature below 146° (assuming atmospheric pressure), while those of type (*b*) were formed above this temperature. It may be noted that the structure of the compound crystals of iodyrite (Fig. 1, p. 46) is identical with that of crystals of eulytite described by Bertrand,[3] and more fully, with figures, by Professor Lewis.[4]

[1] If f and g are present in the same zone $[2\bar{1}\bar{1},\ 111]$ or $[10\bar{1},\ 111]$ the angle $fg_1 = 16°10'$ or $15°30\frac{1}{2}'$, according as the angles of Zepharovich or of Seligmann are taken.

[2] A consideration of the fact that the c axis of iodyrite contracts with rise of temperature before the passage into the cubic modification takes place, suggests that Zepharovich's angles are the more accurate, since with increase in temperature they will gradually approach those of cubic crystals.

[3] Bull. Soc. Min. de France, 1881, IV, 61: compare, however, R. Brauns, Die optischen Anomalien der Krystalle, 1891, p. 333.

[4] Treatise on Crystallography, Cambridge, 1899, p. 478.

Behaviour when heated.—The change in state which silver iodide undergoes at a temperature of about 146° C. is well known. Talbot (1838)[1] first observed that when a film of silver iodide is warmed, its colour changes from pale sulphur-yellow to bright yellow ; and various observers[2] have since shown that the pale yellow variety, which exists at ordinary temperatures, is birefringent and hexagonal, and that with an increase of temperature these crystals undergo a contraction in the direction of the hexagonal axis and an expansion in the directions perpendicular to this axis, while the total volume of the crystal diminishes. When the temperature reaches about 146° C., there is a further sudden contraction of considerable amount accompanied by a change in colour, thermal capacity, electrical conductivity and optical refraction—a denser, cubic and isotropic modification of silver iodide being then called into existence. The same change also takes place at the ordinary temperature, under a pressure of about 3000 kilos per sq. cm. These changes are reversible : on diminution of temperature or pressure the pale yellow hexagonal modification again appears.

When a cleavage plate of iodyrite is heated on a microscope slide there is, at a definite temperature, a sudden change from the pale yellow colour to a bright orange yellow, and at the same time the plate becomes optically isotropic. On cooling, the pale yellow colour suddenly reappears, and the plate is seen, between crossed nicols in parallel light, to become birefringent. The plate, after being heated above this critical temperature, is cloudy, and no longer shows the perfect cleavage nor the uniaxial optic figure, since it now consists of an aggregate of differently orientated crystals of iodyrite.

At a still higher temperature the colour becomes brick-red, and the substance fuses to a deep-red liquid which is almost black by reflected light and which spreads out as a film under the cover-glass. On cooling again, the mass remains isotropic, while the colour gradually changes from brick-red to bright yellow ; then follows a sudden change to the pale yellow birefringent modification, and the line of demarcation between the two can be seen to sweep quickly across the field of view. The slide then shows an aggregate of interlocking lath-shaped crystals, often of considerable size and showing brilliant polarisation colours. The longer direction

[1] H. F. Talbot, Phil. Mag. 1838, XII, 258.

[2] Fizeau (1867), Wernieke (1871), Rodwell (1874, 1876), Lehmann (1877), Bellati and Romanese (1882), Kohlrausch (1882), Mallard and Le Chatelier (1883-5), Schwarz (1892).

of the laths is perpendicular to the principal axis of the iodyrite crystals. With the aid of a micro-spectroscope the change in state on cooling is seen to be accompanied by a sudden increase in the length of the blue end of the spectrum.

IV. Mutual and other Relations.

As explained above, marshite and tetrahedral-cubic silver iodide are isomorphous. The latter when pure is only stable at a temperature higher than 146°, but when it contains a certain amount of copper (5·6 per cent. would be required by the formula 4AgI.CuI) it is stable at ordinary temperatures, and is then distinctive enough to receive the special name miersite. Larger amounts of copper may be present as an isomorphous mixture of marshite; while any excess of silver iodide will, at the ordinary temperature, be represented as iodyrite intimately intergrown with the miersite.

Silver iodide appears to exist also in a third form and therefore to be trimorphous. This is holohedral-cubic and isomorphous with members of the cerargyrite group. It is represented by the AgI in iodobromite (2AgCl.2AgBr.AgI), and as smaller amounts in cerargyrite, embolite and bromargyrite. It may here be mentioned that a mineral[1] similar to *iodobromite* occurs at Broken Hill in New South Wales and at Chañarcillo in Chili. At both these localities it is usually associated with iodyrite, and consists of cubo-octahedra of a bright orange-yellow colour, which soon alters to dark green on exposure to light. The crystals are translucent, and are so tough and sectile that fragments cannot be detached for optical examination without distortion: $H = 2\frac{1}{2}$. There is no distinct cleavage. Chemical tests showed the presence of silver, iodine, bromine and chlorine, all in considerable amount.

The characters of the three modifications may be compared in the following table:

	Iodyrite.	Miersite.	Iodobromite.
System	Rhombohedral	Cubic	Cubic
Class	Hemimorphic	Tetrahedral	Holohedral
Twin-plane	A Rhombohedral face	A tetrahedral face	Not twinned
Cleavage	Perfect basal	Perfect dodecahedral	Indistinct octahedral?
Optically	Uniaxial	Isotropic	Optically anomalous?
	$cg = 54°42'$ or $54°50'$	$oa = 54°44'$	$oa = 54°44'$

[1] An analysis and detailed description of this will be published later. The mineral from Chili was long ago described as cubic silver iodide, by A. Dufrénoy, Traité de Minéralogie, 2nd Edit., 1856, Vol. III, pp. 452, 460.

Really, however, these three modifications of silver iodide only exist as minerals in isomorphous mixtures influenced by the mass effect of other substances, or in definite molecular compounds. They may or may not be identical with the three modifications mentioned by G. F. Rodwell.[1]

The possible existence of two cubic modifications of a compound containing silver iodide has also been suggested above (p. 44) from the behaviour of mixtures of silver iodide and copper iodide when heated. They are also possibly related to the two cubic modifications of mixed crystals of ammonium chloride, bromide and iodide produced by O. Lehmann[2]; these are, however, not beyond doubt, as pointed out by Arzruni.[3]

Lehmann[4] has stated that the cubic modification of silver iodide which is stable above 146° crystallises in octahedra and is isomorphous with cerargyrite: from the present observations, however, it would seem to be the tetrahedral-cubic modification isomorphous with marshite which crystallises out above this temperature.

As mentioned above (p. 47) there is a close connection between the angles of iodyrite and the angles of a cubic crystal; and between miersite and iodyrite there is a still further similarity in the development of the crystals. Some crystals of miersite have the habit of hemimorphic-rhombohedral crystals of iodyrite, while in iodyrite of type (*b*) the habit is identical with that of miersite. These close relations indicate that there must be similarity in crystalline structure,[5] as is often the case with dimorphous minerals, for example, zinc-blende and wurtzite, orthoclase and microcline. In such cases Mallard[6] has suggested the essential identity of these pairs of minerals, the one of higher symmetry being the result of ultra-microscopic twinning of the one of lower symmetry. In the same way crystals of iodyrite of type (*b*) might by repeated twinning give rise to isotropic crystals identical with miersite; but here, as in the case of zinc-blende, the perfect rhombic-dodecahedral cleavage would be difficult to explain, unless it were a parting parallel to the twin-planes *e* of iodyrite, which, in the compound crystals, coincide in direction with the faces of the rhombic-dodecahedron.

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[1] Proc. Roy. Soc. 1874, XXIII, 108; Phil. Trans. 1883 (1882), CLXXIII, 1134.

[2] Zeits. Kryst. Min. 1885, X, 321; "Molekularphysik," 1888, I, 792.

[3] Physik. Chemie d. Krystalle, 1893, p. 321.

[4] Zeits. Kryst. Min. 1877, I, 492; "Molekularphysik," 1888, I, 166.

[5] Related kinds of groupings of the atoms of silver iodide in the rhombohedral and cubic modifications have been suggested by Prof. W. J. Sollas, Proc. Roy. Soc. 1898, LXIII, 289.

[6] Bull. Soc. Min. de France, 1882, V, 325; Ann. des Mines, 1876, [vii], X, 157.

When crystals of iodyrite were first described by Des Cloizeaux, he noticed that in the angles there was a very close relation to greenockite. This relation may also be extended to other mineral species, as shown in the following table :

			$a : c$	Cleavage.
Iodyrite.....	AgI	Hemimorphic-rhombohedral. Optically+	1 : 0·8196	*c* perfect
Wurtzite	ZnS		1 : 0·8175	*a* *c*
Greenockite	CdS		1 : 0·8109	*a* *c*
Zincite	ZnO		1 : 0·8109	*c* perfect

These minerals are placed by F. Rinne[1] in the "magnesium type" of his isotypes: other members are magnesium ($c = 0{\cdot}8195$), niccolite ($c = 0{\cdot}8194$), ice ($c = 0{\cdot}8085$), tridymite ($c = 0{\cdot}8265$), lead iodide ($c = 0{\cdot}8379$), and many others, all of which are chemically simple substances. Some of these are dimorphous, and form another parallel series :

Miersite	(Ag,Cu) I	Tetrahedral-cubic.
Zinc-blende	Zn S	Twinned on a tetrahedron face.
Marshite.....	Cu I	Perfect dodecahedral cleavage.

Nantokite[2] (CuCl) probably belongs to this series. Numerous other substances crystallise in both cubic and rhombohedral modifications (*e.g.* carbon as diamond and graphite), but they do not appear to belong to these series.

Now it will be seen from the above tables that the same relation exists between iodyrite and miersite as exists between wurtzite and zinc-blende :

Hemimorphic-rhombohedral.	Tetrahedral-cubic.	Holohedral-cubic.
Iodyrite	Miersite	Iodobromite
Wurtzite	Zinc-blende	(Schalenblende) ?

As far as crystallographic characters are concerned this is a perfect example of an isodimorphous (perhaps isotrimorphous) group, but

[1] Neues Jahrb. Min. 1894, I, 1 ; 1897, II, 1 ; Zeits. physik. Chemie, 1895, XVI, 529.

[2] The cubic cleavage given by Breithaupt requires verification.

apparently the only chemical relation existing between zinc sulphide and silver iodide is that their simplest conceivable molecules contain two atoms. Isomorphous replacement[1] does not occur, and no apparent relation is shown by the molecular volumes. Isomorphous replacement, however, takes place between miersite and marshite, and between iodobromite and cerargyrite; in the former between the metals, and in the latter between the haloids.

[1] Mentzel has found iodine in a cadmiferous zinc ore from Silesia. Ann. des Mines, 1829 [ii], V, 324; *cf.* Dana, System of Mineralogy, 6th Edit. 1892, p. 161.

Crystallised Stannite from Bolivia.

By L. J. Spencer, M.A., F.G.S.

With Analyses by G. T. Prior, M.A., F.G.S.,

Assistants in the Mineral Department of the British Museum.

(With Plate II.)

[Read November 14th, 1899.]

Historical and Introductory.

VERY little is known of the crystalline form of the somewhat rare mineral stannite, since in the few localities in which it has been found it usually occurs only in the massive state. Several suggestions, summarised below, have been made as to the type of crystalline symmetry of the mineral, but hitherto no crystals have been completely examined.

(1) *Orthorhombic.* Haüy (1822)[1], from an examination of cleavage fragments from Cornwall, concluded that the primitive form might possibly be a right rhombic prism.

(2) *Cubic.* Haidinger (1825)[2] mentioned Cornish crystals, having apparently the form of regular cubes, but the dulness of the faces did not allow of any measurements. The massive material appeared to show cleavages in the directions of the faces of the cube and rhombic dodecahedron. (Crystals of Cornish stannite are further mentioned on p. 65 below.)

(3) *Tetrahedral-Cubic.* Stannite has often been assumed to be a stanniferous fahlerz, and consequently to have the same crystalline form. It appears to have been Breithaupt (1830)[3] who first placed stannite in this systematic position, and assigned to it this type of symmetry.

Later, Breithaupt (1866)[4] mentioned large triakistetrahedra from Peru,

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[1] Traité de Minéralogie, 2nd Edit. 1822, Vol. IV, p. 170.

[2] English translation of Mohs' Mineralogy, 1825, Vol. III, p. 163.

[3] Uibersicht des Mineral-Systems, 1830, p. 75. Vollständige Char. d. Mineral-Systems, 3rd Edit. 1832, p. 275.

[4] Berg- und hüttenmänn. Zeitung, 1866, XXV, 181; and Min. Studien, 1866, p. 102

but these have since been shown[1] to be only tetrahedrite. In 1884 vom Rath[2] mentioned a similar large crystal, also from Peru, as existing in the collection of Mr. C. S. Bement, of Philadelphia. While on a visit to London, in December, 1899, Mr. Bement informed me that this crystal is very indistinct, and that it is no longer considered to be stannite.

More recently Stelzner[3] has described crystallised stannite from Potosi, Bolivia. The crystals are 5 mm. across and show the cubic forms $+o\{111\}$ and $-o\{1\bar{1}1\}$, with subordinate $d\{110\}$, $a\{100\}$ and $\kappa\{hkk\}$, but goniometric measurements do not appear to have been made. The crystals gave the blowpipe reactions of stannite, and a quantitative chemical analysis was made of the accompanying massive material. These crystals, which are the most distinct yet described, are stated by Stelzner to be frequently built up of sub-individuals: this suggests that they are probably only pseudo-cubic, and like the crystals to be described in the present paper.

(4) *Scalenohedral-Tetragonal.* Kenngott (1849)[4] considered stannite to be a stanniferous copper-pyrites, and remarked that Haidinger's cubes could equally well be considered to be tetragonal with the same symmetry as copper-pyrites. This view was supported by Delafosse.[5]

Of these types of symmetry the third—tetrahedral-cubic—is the one now generally accepted for the mineral. It will, however, be shown below that the crystals really belong to the fourth type, namely scalenohedral-tetragonal, but that by twinning the symmetry becomes pseudo-tetrahedral-cubic.

The specimen (Brit. Mus. No. 84686) which supplied crystals for the present investigation is from the San José Mine at Oruro, Bolivia; it was obtained by Sir W. Martin Conway, while on his Bolivian Expedition in 1898, and was, with several other Bolivian specimens,[6] presented by

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[1] A. W. Stelzner, Zeits. Deutsch. geol. Ges. 1897, XLIX, 75; and Dana's System of Mineralogy, 6th Edit. 1892, p. 83.

[2] Verh. Ver. Rheinl. Bonn, 1884, XLI, 296; Compare A. W. Stelzner, Zeits. Deutsch. geol. Ges. 1897, XLIX, 75.

[3] Zeits. Deutsch. geol. Ges. 1897, XLIX, pp. 97, 131; abstract Min. Mag. 1898, XII, 46. Stelzner's crystals were first mentioned in Zeits. Deutsch. geol. Ges. 1892, XLIV, 531; abstract Min. Mag. 1893, X, 261.

[4] Min. Untersuchungen, 1849, I, p. 11; Kenngott's Uebersicht (1841-9), 1852, p. 237.

[5] Nouveau Cours de Minéralogie, 1860, II, 416.

[6] An account of this collection will be published as an Appendix to Sir Martin Conway's book, "Bolivian Andes."

him to the British Museum. This specimen consists of radiating groups of prismatic crystals of mispickel, on which are a few bright crystals of andorite and pyrites. Encrusting all these minerals is the stannite, which occurs abundantly as crystalline crusts and as isolated crystals. As a later encrustation are minute white globules of an undetermined mineral.

The occurrence of crystallised stannite at Oruro has been previously mentioned by d'Orbigny [1] but the only information given by him is: "On n'exploite à Oruro qu'un riche filon d'étain du sommet de la montagne; filon composé d'étain sulfuré presque pure, souvent cristallisé."

Crystallography.

The crystals average 1—1·5 mm. across; the largest is 3 mm. Many of them are irregularly aggregated in crusts and partly embedded, and are consequently difficult to decipher, but those which are more isolated show very distinctly the form illustrated in Fig. 3, Plate II. They have the appearance of cubic crystals, but on closer examination they are at once seen to be composite. The faces are usually striated and rough, and on the goniometer they give several scattered images. A first series of approximate measurements was not good enough to distinguish the angles from those of a cubic crystal, but at the same time it was observed that the striations and characters of the faces agree only with scalenohedral-tetragonal symmetry. A second series of measurements carefully made on the best crystals, however, showed that the angles also agree with tetragonal and not with cubic symmetry.

The inclined hemihedral (scalenohedral) character is not a striking feature, and was not at first noticed,[2] but when the crystals are examined closely the differences in adjacent octants may easily be seen (Figs. 1—4). In one set of (positive) octants the planes of $p\{111\}$ and $n\{211\}$ are bright and smooth and the edges sharp, while in the adjacent (negative) octants p and n are represented by rather larger faces, which are here rough. The faces of n being larger cause the pits (Fig. 3) in the negative octants to be shallower, owing to the exclusion in many cases of the faces of $c\{001\}$.

[1] Voyage dans l'Amérique méridionale, 1826—1833, Tome III, 3e Partie, Géologie, p. 129, 1842. Stelzner (*loc. cit.* p. 86) has doubted this occurrence, but without sufficient reason.

[2] The figures prepared for the preliminary account in Sir Martin Conway's book, "Bolivian Andes," represent the crystals as holohedral.

The forms[1] noticed on the crystals measured are given below; with the exception of *a d t u* they are well developed on all crystals.

c{001}. Bright and smooth. On crystals which are in part simple it is present as a rather large face (Fig. 1), but in the twinned groups it is only present as small faces, forming the deep pits (Fig. 3).

a{100}. Usually only represented by striæ on *z*{201}, but on crystals from one specimen (described on p. 64 below) it is present as a bright narrow face on the edge [*zz*].

m{110}. Bright, but usually deeply striated, owing to its oscillation with $+p\{111\}$ and $-p\{1\bar{1}1\}$. The twinning makes this the most prominent face on the crystals.

e{101}. Bright; striated horizontally.

z{201}. Deeply striated horizontally, the striæ reflecting light with *e*{101} and *a*{100}.

$+d\{114\}$. Very narrow planes on the edge between $+n$ and *c*; deeply striated parallel to this edge. Other reflections from striæ were obtained near the positions of {229} and {223} also in the positive octants.

$+n\{112\}$. Bright and smooth; small.

$+p\{111\}$. Bright and smooth; small. This and $+n$ are faintly striated parallel to their mutual intersection.

$+t\{221\}$. Observed only once as a very narrow striation on the edge $[+p,m]$.

$-n\{1\bar{1}2\}$. Dull and rough; rather larger than $+n$.

$-p\{1\bar{1}1\}$. Dull and rough; usually rather larger than $-p$, but sometimes quite small.

$+u\{423\}$. Minute bright faces in the zone [201, 111, 021]. On two crystals.

About a dozen crystals were measured on the goniometer, but reliable measurements could be obtained from only a few. Only portions of simple crystals can be observed, and it is not always easy to separate the reflections belonging to each individual. Even portions of crystals, which

[1] The letters adopted for the forms are those used in Dana's Mineralogy (6th Ed. 892) for copper-pyrites. For these forms to be strictly analogous with those of copper-pyrites + and — would probably have to be interchanged.

are at first sight apparently simple, were usually found on more careful examination to show twin-lamellæ. The results of the measurements are:

	Measured.	Limits.	No. of edges.	Calculated.	Copper-pyrites (Haidinger).	Corresponding Cubic angles.
$ce = 001 : 101$	*44° 30′	42°24′ — 44°38′	10	—	44° 34½′	45° 0′
$cz = 001 : 201$	63 8	62 57 — 63 15	7	63° 2′	63 5½	63 26
$cd = 001 : 114$	19 9	18 — 20	8	19 9½	19 12½	19 28
$cn = 001 : 112$	34 44	34 16 — 35 4	9	34 48	34 52	35 16
$cp = 001 : 111$	54 15	54 1 — 54 38	19	54 16	54 20	54 44
$cm = 001 : 110$	89 57	89 54 — 90 2	9	90 0	90 0	90 0
$tp = 221 : 111$	16	—	1	15 57	15 55½	15 47¼
$en = 101 : 112$	29 46	29 41 — 29 52	4	29 42½	29 45	30 0
$ee' = 101 : 011$	59 35	59 30 — 59 40	2	59 25	59 30	60 0
$em = 101 : 110$	60 7	60 5 — 60 8	4	60 17½	60 15	60 0
$pu = 111 : 423$	15 11	15 0 — 15 18	3	15 8½	15 9	15 13½
$mm' = 110 : 110$	90 0	89 58 — 90 5	5	90 0	90 0	90 0

Twinning.—The most interesting feature of the crystals is the twinning, which gives rise to pseudo-cubic forms, and is invariably present. The two twin-laws are:—

(i) Interpenetrant symmetric twins with $c(101)$ as twin-plane, the two individuals being symmetrical to each other with respect to this plane.

(ii) Interpenetrant twins with the twin-axis perpendicular to $p(111)$ Also juxtaposed twins (Fig. 4) with the same twin-axis and $p(111)$ for the plane of combination.

The first law, on which every crystal is twinned, is illustrated by Figs. 2 and 3, and the stereographic projection, Fig. 5. The ideal simple crystal (Fig. 1), when reflected across the plane (011), gives the interpenetrating doublet shown in Fig. 2, and when also reflected across the homologous plane (101) the three interpenetrating individuals produce a figure closely resembling a regular rhombic dodecahedron in appearance (Fig. 3). In each octant three planes of the tetragonal sphenoid $p\{111\}$ come together, and correspond to the regular tetrahedron; these faces bound the edges of deep triangular pits formed by three faces of $n\{112\}$ and three faces of the basal planes $c\{001\}$, the latter being in the twinned position approximately parallel to the three faces of the cube. The prism

ces $m\{110\}$ of the simple crystals form the faces of the pseudo-dodecahedron, the edges of which are replaced by V-shaped grooves formed by the faces of $e\{101\}$. Owing to a frequent oscillation between $e\{101\}$ and $\{201\}$, these grooves gradually widen out towards the pseudo-tetrad axes. Each pseudo-dodecahedral face m is very nearly parallel to four portions of two e faces in the opposite sides of the four grooves adjacent to it. The striations on these planes m and e, which are nearly parallel, and sometimes in the actual crystals nearly co-planar, are approximately at right-angles (really $90°42\frac{1}{2}'$); and it was this character which suggested in the first place that the crystals could not be parallel groupings of cubic sub-individuals. Doublets resembling Fig. 2 are rarely present in the specimen, and there are always indications of a third individual. Crystals like Fig. 3 are common, and are often as symmetrically and regularly developed as shown in the drawing; in some cases they are developed on nearly all sides, one crystal showing six of the eight possible triangular pits. From the projection (Fig. 5)[1] it will be seen that in the two opposite octants XYZ and $\overline{X}\overline{Y}\overline{Z}$ the sphenoidal planes $p\{111\}$ of the three individuals are coincident, while in the two octants $\overline{X}\overline{Y}Z$ and $XY\overline{Z}$ all three planes of $p\{111\}$ are separate; in each of the remaining four octants two sphenoidal planes coincide and the third is separate. Each pole m of the pseudo-dodecahedron nearly coincides with two poles e, except in the positions (101) and (011) where there is only one pole e. Although approximating to cubic symmetry, it will be seen from the projection that there is only one plane of symmetry to the whole group of three crystals.

The following (p. 60) are the observed and calculated (from $ce = 44°30'$) angles, when the crystals are twinned on $e(101)$ and (011).

These measured and calculated angles are not in close agreement. The images were often scattered, and not very good; further, it was not always possible to distinguish to which individuals the various reflections belonged, especially when the crystals are further complicated by twinning in the second law.

It was not possible to distinguish between $c\bar{c}$ (or cc) and $\bar{c}\bar{c}$, or between $p\bar{p}$ (or pp) and $\bar{p}\bar{p}$. Only on one crystal could more than one of the

[1] The angle ce in the projection has been taken as $43\frac{1}{2}°$, instead of $44\frac{1}{2}°$, in order to separate more distinctly the poles which nearly coincide. The poles of the crystal in the normal position are indicated by unbarred letters, those of the crystal twinned about (101) are indicated as $\bar{c}\,\bar{e}$, etc., and those twinned about (011) as $\bar{e}$, etc. The parallel planes beneath the plane of projection are omitted.

	Calculated.	Measured.
$p\bar{p}=p\underline{p}$	1° 38¼′	1°29′, 1°29′, 1°24′, 1°10′, 1°10′, 1°6′, 1°5′, 53′, 35′.
$\underline{p}\bar{p}$	1 37½	
$c\bar{c}=c\underline{c}$	89 0	Numerous readings between the limits 89°11′ and 90°33′.
	91 0	
$\underline{c}\bar{c}$	89 59	
$m\underline{e}=\bar{m}e=$etc.	0 52	
$e\bar{e}=\underline{e}\underline{e}$	2 0	
$\underline{e}\bar{e}$	1 25½	1°27′.

angles $p\bar{p}$, etc., in the same octant be fairly accurately measured: the results were 1°10′ and 1°6′. In the same pit the angles between the three planes of $c\{001\}$ were measured as 90°33′, 90°30′, 90°22′, and in another pit as 90°32′, 90°26′, 90°12′. The portions of the planes of $c\{001\}$ in adjacent octants are never quite parallel, the angles 43′, 25′, 20′, etc. being measured; even apparently single c planes in the same octant sometimes give two sharp images measured at 21′, 22′, etc. apart.

Twinning on the second law, in which the twin-axis is (111), though common, is not invariably present, as is twinning on the first law. The pseudo-dodecahedra (Fig. 3) described above give rise to the juxtaposed twin shown in Fig. 4, or two interpenetrate.[1] Twin lamellæ may also often be seen running through the crystals. As shown in Fig. 4, these are not symmetric twins as in the first law.

The calculation of the angles of crystals twinned on the second law is much simplified if it is assumed that the three twin-planes (101), (011) and (111) all have positive indices[2]; the twin-plane (111) will then be exactly coincident for all three simple individuals, and the twin-axis will be strictly parallel to the zone-axis of the pseudo-hexagonal zone formed by six m planes. Several planes of $e\{101\}$ will be slightly out of this pseudo-hexagonal zone, and when twinned on (111) they will form with each other across this zone angles of 1°38¼′; the corresponding measured values were 1°13′ and 1°10′. The prominent striations on the m faces make, in the twin crystals (Fig. 4), an angle of 108°31½′. It was not, however, possible to prove that the four twin-planes all have positive

[1] Compare the interpenetrating dodecahedra of argyrodite figured in Min. Mag. 1898, XII, 7.

[2] In Fig. 4 the twin-plane is $(\bar{1}11)$.

dices, and it is quite possible that another combination of homologous anes might account for the irregularities between the measured and lculated angles noted above.

The pseudo-cubic groups described above remind one of the pseudo- decahedra of phillipsite, and also of the several cubic minerals exhibiting btical anomalies; but in these cases the groupings are usually more mplex than the twinning together of three tetragonal individuals.[1]

Physical Characters.

The colour of the stannite crystals is iron-black, with a bright metallic sub-adamantine lustre, somewhat resembling black blende. On one ecimen (described below) the crystals have a bronze-coloured tarnish on e surface. The mineral is opaque. The streak is black and dull. The ystals are not very brittle; H = $3\frac{1}{2}$. The fracture is sub-conchoidal to neven; no cleavage was observed.[2] Specific gravity 4·45.[3]

Chemical Composition.

The material collected for analysis consisted mainly of well-developed ystals projecting from the surface of the specimen, but some of the derlying crystalline material was also collected in the belief that it as all stannite; the latter, however, contained some andorite, as ggested by the results of the analysis, and as actually seen to be the se upon a further and more careful examination of the specimen.

The results of the analyses by Mr. G. T. Prior are given below under lumns I-V. Analysis I was made on 0·3678 gram of material, which as decomposed with nitric acid; in II, 0·4215 gram was fused with dium carbonate and sulphur, and the tin obtained in solution as sodium lpho-stannate; for the sulphur determination (III) 0·2233 gram was sed with sodium carbonate and potassium nitrate. The mean of these alyses is given under IV. Germanium was tested for, but found to be sent:—

	I.	II.	III.	IV(Mean).	Atomic ratios.
Cu ...	28·58	28·54		28·56	·453
Fe ...	10·95	10·90		10·93	·197
Sn ...	25·52	24·90		25·21	·213
Sb ..	3·54	3·88		3·71	·031
Pb ...	2·02	2·09		2·06	·010
Ag ...	0·94	0·82		0·88	·008
S ...	—	—	27·83	27·83	·874
				99·18	

[1] Compare the pseudo-cubic crystals of iodyrite described in this number of the agazine, p. 46.

[2] Crystals of Cornish stannite appear to possess cleavages, see pp. 54, 65.

[3] Calculated from the specific gravity of the material analysed (4·52) by deducting 58 per cent. of andorite (sp. gr. 5·35).

The atomic ratios of Sb, Pb and Ag are approximately those required by he andorite formula $PbAgSb_3S_6$; and the atomic ratios of Cu : Fe : Sn : remaining S = ·453 : ·197 : ·213 : ·814, agree approximately with the formula Cu_2FeSnS_4 for stannite. Under column V below is given the percentage composition of the stannite after deducting Sb_2S_3, PbS and Ag_2S. Column VI gives the calculated percentage composition required by the formula Cu_2FeSnS_4 :—

	V.	VI(Cu_2FeSnS_4).
Cu ...	31·52 ...	29·54
Fe ...	12·06 ...	13·01
Sn ...	27·83 ...	27·65
S ...	28·59 ...	29·80
	100·00	100·00

This analysis, which is the first that has been made on crystallised stannite, therefore supports the empirical formula usually given for the mineral, namely Cu_2FeSnS_4.

This formula has been written by various authors in many different ways, of which only the following two need be mentioned here:— $Cu_4SnS_4 + Fe_2SnS_4$ represents an orthostannate, and $CuFeS_2 + CuSnS_2$ shows a possible relation to copper pyrites ($CuFeS_2$).

Relation between Stannite and Copper-pyrites.

The remarkably close crystallographic relation existing between stannite and copper-pyrites may now be pointed out. The type of symmetry—scalenohedral-tetragonal—is the same for both, and the angles are almost identical. The angular element (*ce*, 001 : 101 = 44°30′) given above for stannite lies between the usually accepted value for copper-pyrites, namely 44°34½′ (Haidinger), and that obtained by Mr. Fletcher[1] on crystals from Freiberg, Saxony, namely 44°22′. The crystal forms[2] and character of the faces are also similar. Further, the twin-laws[3] are the same, including the remarkable symmetric twins, of which very few examples are known among minerals. Pseudo-cubic crystals, as the

[1] Phil. Mag. 1882 [v], XIV, 287; Proc. Cryst. Soc. 1882, p. 126; Zeits. Kryst Min. 1883, VII, 331.

[2] For the stannite forms to be strictly analogous with those of copper-pyrites + and — as given above, would probably have to be interchanged; if this is done all the stannite forms, with the exception of $-n\{1\bar{1}2\}$, have been noted on copper pyrites.

[3] A third, but very rare, twin-law of copper-pyrites is represented by the complementary interpenetrant twins with $m(110)$ as twin-plane: this has not been observed on the stannite crystals.

result of twinning, have long ago been figured by Haidinger[1] for copper-pyrites, and one of his figures represents a pseudo-cubic crystal again twinned on $p(111)$ as in Fig. 4 above.

As far as crystallographic characters are concerned stannite and copper-pyrites are therefore practically identical; and, as pointed out above, a possible chemical relation is suggested when the formula of stannite is written in the form $CuFeS_2 + CuSnS_2$ (that of copper-pyrites being $CuFeS_2$). There is absolutely no evidence to support the possible suggestion that the crystals described in the present paper may be pseudomorphs of stannite after copper-pyrites: the implanted crystals are quite sharp and homogeneous, and not a trace of copper-pyrites was seen on any of the Bolivian specimens.

The supposed relation (p. 54) between stannite and fahlerz receives some support in the fact that the composite twinned crystals of stannite simulate the symmetry of fahlerz.

Other Specimens of Crystallised Stannite.

Oruro, Bolivia.—Besides the specimen described above there are three others, brought by Sir Martin Conway from Oruro, on which are crystals of stannite. As the characters of the stannite and the associated minerals are somewhat different in each of these a brief description is now given.

The largest specimen (Brit. Mus. No. 84687) consists of a matrix of massive quartz, pyrites and tetrahedrite, with the free surface, measuring about 28×23 cm., covered with good crystals of augelite,[2] mispickel, quartz and pyrites, together with some powdery kaolinite and minute yellow globules of cervantite (?). On this surface are abundant drusy black crusts of stannite, but the form of the minute crystals cannot, as a rule, be made out even under the microscope. On parts of the specimen, however, where the stannite is more coarsely crystallised, the characteristic twinning described above can sometimes be distinguished. Small cavities at the back of the specimen contain good crystals of wolfsbergite,[3] andorite and stannite, the last like Fig. 3.

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[1] Memoirs Wernerian Nat. Hist. Soc. Edinburgh, 1822, Vol. IV. p 17, Figs. 37-41; Edinb. J. Sci. 1825, Vol. III, Plate III, Figs. 29, 32, 34. Two of Haidinger's figures are reproduced in Mr. Fletcher's paper (*loc. cit.*).

[2] This is the fourth locality at which the rare mineral augelite has been found. Compare Min. Mag. 1898, XII, p. 1.

[3] This is a new locality for the rare mineral, wolfsbergite (=chalcostibite). Compare Min. Mag. 1897, XI, 338. These occurrences are described in the Appendix to Sir Martin Conway's book, "Bolivian Andes."

Another specimen (No. 84689) consists of an aggregate of jamesonite needles encrusted with small crystals of pyrites and stannite, the latter showing the complex twinning.

On the fourth specimen (No. 84684) some of the stannite crystals are of quite a different type. This is from the San José mine, and is a large piece of massive tetrahedrite with massive quartz and pyrites. One cavity is almost completely lined with crystals of stannite, which have a bronze coloured tarnish on the surface; they are about a millimeter across, and are confusedly grown together forming a crust. The faces are bright, and smoother than those of the crystals described above. Two of the partially embedded crystals were measured on the goniometer; each showed one large plane of the form $m\{110\}$, surrounded at the edges by smaller faces of $z\{201\}$, $a\{100\}$, $e\{101\}$ and $n\{112\}$. They are twinned on $p(111)$, one crystal being twinned on two planes of this form: no twinning on the plane $e(101)$ was detected on these crystals. Other cavities in this specimen contain black crystals of stannite, like those figured above, together with crystals of wolfsbergite, andorite, quartz and pyrites.

Potosi, Bolivia.—A small specimen (No. 84075) from this locality was supplied to the Museum in 1898 by Messrs. G. L. English and Co. of New York. It consists of massive quartz, pyrites and tetrahedrite, with crystals of quartz, mispickel and stannite in cavities. The stannite crystals are black with a brilliant metallic to sub-adamantine lustre; they are very small and closely aggregated together. On the goniometer only approximate measurements could be obtained; all that could be determined was a triangular face bounded at the edges by three narrow planes at angles of about $35\frac{1}{4}^{c}$ with the triangular face. The triangular faces gave two, three or more images (one pair at 48′ apart), but no pits, as shown in Fig. 3, were seen. The crystals are too imperfect to show whether they are pseudo-cubic, or cubic with the forms $o\{111\}$ and $d\{110\}$.

The association of minerals on this specimen is the same as on the specimen from Potosi described by Stelzner (p. 55), but his crystals of stannite were larger and probably more distinct.

Tatasi, Bolivia.—This specimen (No. 84324) from the Carmen vein in the silver mine at Tatasi, prov. Sud-Chichas, dept. Potosi, was presented to the Museum by my friend Mr. Malcolm Roberts, A.R.S.M., Administrator of Mines to the Compañia Guadalupe de Bolivia. The matrix is a white, altered volcanic tuff with blebs of quartz and numerous veins and specks of pyrites. On the free surface are crystals of quartz, pyrites and stannite, the last being in very indistinct rounded crystals or groups

of crystals, up to 3 mm. across, with a black drusy surface. The stannite encrusts pyrites, and sometimes there is only a shell of material enclosing pyrites. The most distinct crystal appears to be cubic with the form of a deltoid-dodecahedron $\kappa\{hhk\}$, and it further appears to show signs of being composite like the Oruro crystals described above.

Cornwall.—Only two of the several specimens of Cornish stannite in the British Museum show any signs of crystals; and these are similar to the imperfect crystals mentioned by Haidinger in 1825 (see p. 54 above). The specimens, which are labelled Cornwall (No. 19109) and Wheal Rock, St. Agnes (No. 33475), consist of compact granular stannite, showing in places indications of a poor cleavage; the colour is dark steel-grey, with a yellowish tinge owing to the presence of intermixed copper-pyrites. On the walls of cavities in the massive material are a few distorted cubes or short square prisms of stannite, which measure up to 2 mm. in cross-section; a few crystals are much elongated and measure $8 \times 1 \times 1$ mm. The faces of these crystals are very dull and uneven, and are encrusted with numerous minute crystals of copper-pyrites. Approximate measurements on the goniometer gave angles of about 90°. There appears to be a fair cleavage perpendicular to the length of the prism, and possibly another cleavage parallel to the faces of the prism. These crystals may therefore be tetragonal with the basal pinacoid and one prism. The colour of the crystals is the same as of the massive material, and the streak is dull black.

Crystals from all the specimens mentioned above were examined chemically by Mr. Prior, and in each case found to contain copper, iron, tin and sulphur.

EXPLANATION OF PLATE II.

Fig. 1.—An ideal simple, scalenohedral-tetragonal crystal of stannite, with the forms. $c\{001\}$, $m\{110\}$, $e\{101\}$, $z\{201\}$, $+p\{111\}$, $-p\{1\bar{1}1\}$, $+n\{112\}$, $-n\{1\bar{1}2\}$.

Fig. 2.—The same twinned on (011).

Fig. 3.—The same twinned on (011) and (101), producing a pseudo-cubic compound crystal.

Fig. 4.—A pseudo-cubic crystal, as in Fig. 3, further twinned on $p(\bar{1}11)$.

Fig. 5.—Stereographic projection of Fig. 3 (*see* footnote on p. 59).

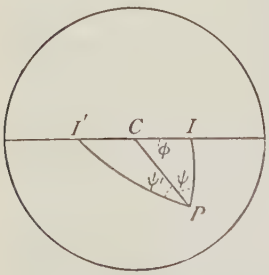
On a Question relative to Extinction-angles in Rock-slices.[1]

By Alfred Harker, M.A., F.G.S.

[Read January 22nd, 1901.]

MANY minerals of the rhombic system are of markedly columnar habit, with the axis of elongation, or vertical axis, as one of the bisectrices of the angles between the optic axes. Such a crystal, in a section parallel to the vertical axis, gives straight extinction. It is natural to expect, and is perhaps generally assumed, that a section slightly oblique to the vertical axis will give nearly straight extinction. The object of the present note is to inquire how far this is true, and in what possible cases a serious error may arise.

Let P in the figure be the pole of the plane of section; C, I, I' the points corresponding with the vertical axis and the two optic axes.



Let $CI = V = CI'$; $CP = \frac{\pi}{2} - \theta$, so that θ is the obliquity of the section; the angle $ICP = \phi$; and the angles CPI and $CPI' = \psi$ and ψ' respectively.

Then by solving the triangles CPI, CPI', we have—

$$\tan \psi = \frac{\sin V \sin \phi}{\cos V \cos \theta - \sin V \sin \theta \cos \phi},$$

$$\tan \psi' = \frac{\sin V \sin \phi}{\cos V \cos \theta + \sin V \sin \theta \cos \phi}.$$

Taking for the extinction-angle (ε) the angle which the internal bisector of IPI' makes with PC, we have—[2]

$$2\varepsilon = \psi - \psi'.$$

There are two cases to be distinguished, according as θ is less or greater than $\frac{\pi}{2} - V$. We take the former and more important case first.

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[1] Compare "Extinction-Angles in Cleavage-Flakes." By Alfred Harker. Min. Mag. 1893, Vol. X, p. 239.

[2] The extinction-angle is here reckoned from the projection of the vertical axis. In practice it would be measured from the trace of some pinacoid or prism-plane, but for a small degree of obliquity the difference is negligible.

If then θ is less than $\frac{\pi}{2}-V$, and therefore CP greater than CI, $\varepsilon=0$ both for $\phi=0$ and for $\phi=\frac{\pi}{2}$, and reaches a maximum for some intermediate value of ϕ, θ being supposed given. From the above relations we obtain without difficulty

$$\tan^2\phi(\sin^2V+\cos^2V\cos^2\theta)-2\tan\phi\sin^2V\sin\theta\cot2\varepsilon+(\cos^2\theta-\sin^2V)=0,$$

an equation giving two values of ϕ between 0 and $\frac{\pi}{2}$ for a given value of ε less than the maximum. To find this maximum we make the two values of ϕ equal. The condition for this is

$$(\sin^2V\sin\theta\cot2\varepsilon)^2=(\sin^2V+\cos^2V\cos^2\theta)(\cos^2\theta-\sin^2V),$$

which reduces to

$$\sin 2\varepsilon=\frac{\sin V\tan V}{\cos\theta\cot\theta}.$$

The accompanying table is calculated from this simple relation. It gives the highest extinction-angles that can occur in sections of different degrees of obliquity. It is to be observed that $2V$ is here the angle between the optic axes measured over C, *i.e.* so that the vertical axis bisects it. The table shows that sections with a small obliquity will not give any considerable departure from straight extinction, except when $2V$ is a wide angle. Indeed it is a rough general rule that the maximum extinction-angle is less or greater than the obliquity of the section, according as $2V$ is less or greater than 130°.

It would be easy, if desired, to find the chance that a random section of given obliquity would have an extinction-angle higher than a given value (ε); for this chance is evidently the ratio of $\phi_1-\phi_2$ to $\frac{\pi}{2}$, where $\tan\phi_1$ and $\tan\phi_2$ are the roots of the equation given above, and it can be shown that

$$\tan(\phi_1-\phi_2)=\frac{2\sqrt{(\sin^4V\sin^2\theta\operatorname{cosec}^2 2\varepsilon-\cos^2V\cos^4\theta)}}{(1+\cos^2V)\cos^2\theta}.$$

Finally, if θ is greater than $\frac{\pi}{2}-V$, and therefore CP less than CI, it is easy to see that there is no limit to the extinction-angle. As ϕ changes from 0 to $\frac{\pi}{2}$, ε changes from $\frac{\pi}{2}$ to 0, passing through all intermediate values.

Values of $2V$.	Values of θ.								
	1°	2°	3°	4°	5°	10°	15°	20°	30°
20°	0°	0°	0°	0°	0°	0¼°	0½°	0¾°	1°
30	0	0	0	0¼	0¼	0½	0¾	1	1½
40	0	0¼	0¼	0¼	0¼	0¾	1	1½	2½
50	0	0¼	0¼	0½	0½	1	1½	2¼	3¾
60	0¼	0¼	0½	0½	0¾	1½	2¼	3¼	5½
70	0¼	0½	0½	0¾	1	2	3¼	4½	7¾
80	0¼	0½	0¾	1	1¼	2¾	4¼	6	10½
90	0¼	0¾	1	1½	1¾	3½	5¼	8	14
100	0½	1	1¼	1¾	2¼	4¾	7¼	10¼	18¾
110	0½	1¼	1¾	2¼	3	6	9½	13½	25¾
120	0¾	1½	2¼	3	3¾	7¾	12¼	17¾	—
130	1	2	3	4	5	10¼	16¼	24½	—
140	1¼	2½	4	5¼	6½	16	22¾	—	—
150	1¾	3½	5½	7¼	9¼	20	—	—	—
160	2¾	5¾	8½	11½	14¾	—	—	—	—
170	5½	11¾	18¼	26½	—	—	—	—	—

A simple proof of the rationality of the anharmonic ratio of four faces of a zone.

By Harold Hilton, B.A.,

Fellow of Magdalen College, Oxford.

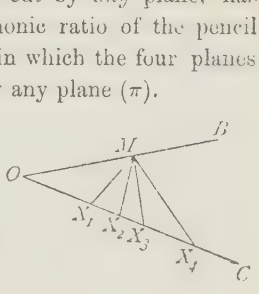
(Communicated by Prof. H. A. Miers.)

[Read November 13th, 1900.]

THE anharmonic ratio here considered is that of the pencil (I') formed by the four lines (lying in a plane perpendicular to the zonal axis) drawn from any point M perpendicular to four faces of the zone. The anharmonic ratio of the pencil I' is evidently independent of the position of M.

Let four planes be drawn through M perpendicular to the four lines of the pencil I'; these are parallel to the crystal faces and meet in a line (the line through M perpendicular to the plane of the pencil P and parallel to the zonal axis).

These four planes are cut by the plane of the pencil in a pencil having the same angles, and therefore the same anharmonic ratio, as the pencil P. Now it is a well-known theorem that the pencil in which four planes through a line are cut by *any* plane, has a constant anharmonic ratio; hence the anharmonic ratio of the pencil I' is equal to the anharmonic ratio of the pencil in which the four planes through M parallel to the crystal faces are cut by any plane (π).



Let OA, OB, OC, be the positions of the crystallographic axes, and a, b, c their lengths. We noticed above that the anharmonic ratio of the pencil P is independent of the position of its vertex M; we may take M therefore on the axis OB, and take the plane of OB, OC as the plane (π).

Let $h_1k_1l_1$, $h_2k_2l_2$, $h_3k_3l_3$, $h_4k_4l_4$ be the indices of the four faces; then their intercepts on the axes are

$$\frac{a}{h_1}, \quad \frac{b}{k_1}, \quad \frac{c}{l_1}, \quad \&c.$$

Let OC cut the four planes through M parallel to the crystal faces in X_1, X_2, X_3, X_4. Then we have proved that the pencil P has the same anharmonic ratio as the pencil $M\ (X_1X_2X_3X_4)$; *i.e.* as the range $(X_1X_2X_3X_4)$.

Therefore the anharmonic ratio of the pencil P

$$= \frac{(OX_3 - OX_1)\ (OX_4 - OX_2)}{(OX_4 - OX_1)\ (OX_3 - OX_2)}.$$

Now, $\dfrac{OX_1}{OM} = \dfrac{\frac{c}{l_1}}{\frac{b}{k_1}} = \dfrac{ck_1}{bl_1}$, &c.

or $OX_1 = OM\,\dfrac{ck_1}{bl_1}$; $OX_2 = OM\,\dfrac{ck_2}{bl_2}$; $OX_3 = OM\,\dfrac{ck_3}{bl_3}$; $OX_4 = OM\,\dfrac{ck_4}{bl_4}$

and therefore the ratio of the pencil P

$$= \frac{\left(\frac{ck_3}{bl_3} - \frac{ck_1}{bl_1}\right)\left(\frac{ck_4}{bl_4} - \frac{ck_2}{bl_2}\right)}{\left(\frac{ck_4}{bl_4} - \frac{ck_1}{bl_1}\right)\left(\frac{ck_3}{bl_3} - \frac{ck_2}{bl_2}\right)} = \frac{(l_1k_3 - l_3k_1)\ (l_2k_4 - l_4k_2)}{(l_1k_4 - l_4k_1)\ (l_2k_3 - l_3k_2)}.$$

which is rational, for l_1, l_2, l_3, l_4 and k_1, k_2, k_3, k_4 are rational.

Exactly similarly it may be proved that the ratio P

$$= \frac{(k_1h_3 - k_3h_1)\ (k_2h_4 - k_4h_2)}{(k_1h_4 - k_4h_1)\ (k_2h_3 - k_3h_2)} = \frac{(h_1l_3 - h_3l_1)\ (h_2l_4 - h_4l_2)}{(h_1l_4 - h_4l_1)\ (h_2l_3 - h_3l_2)}.$$

Addition to a former note[1] *on the rotation of points and planes about an axis.*

By R. W. H. T. Hudson, B.A.,

Fellow of St. John's College, Cambridge.

(Communicated by Prof. W. J. Lewis, M.A.)

[Read January 22nd, 1901.]

THE evaluation of the determinant

$$\Delta_1 = \begin{vmatrix} l_1 & m_1 & n_1 \\ \cos\lambda & \cos\mu & \cos\nu \\ x & y & z \\ OP & OP & OP \end{vmatrix}$$

occurring at the foot of page 345, Vol. XII, can be effected without first squaring it. Multiply Δ_1 by

$$(1+2\cos\alpha\cos\beta\cos\gamma-\cos^2\alpha-\cos^2\beta-\cos^2\gamma)^{\frac{1}{2}},$$

say $D^{\frac{1}{2}}$, which is the value of the determinant

$$\begin{vmatrix} l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \\ l_3 & m_3 & n_3 \end{vmatrix}.$$

The result is

$$\Delta_1 D^{\frac{1}{2}} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ \cos\theta_1 & \cos\theta_2 & \cos\theta_3 \end{vmatrix}.$$

Similarly Δ_2 and Δ_3 may be evaluated.

Further D_1 (p. 347) is the value of $\rho^{-1}\Delta_1$ after ph/a, pk/b, pl/c have been substituted for $\cos\theta_1$, $\cos\theta_2$, $\cos\theta_3$ respectively. Accordingly[2]

$$D_1 D^{\frac{1}{2}} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ h/a & k/b & l/c \end{vmatrix}.$$

[1] Min. Mag. 1900, Vol. XII, p. 343.

[2] This result is due to Mr. T. J. I'A. Bromwich, M.A., Fellow of St. John's College, Cambridge.

Thus the final formulæ (7) are :

$$\frac{h'}{a}-\frac{h}{a}\cos\phi=$$

$$\sin\phi\, D^{-\frac{1}{2}}\begin{vmatrix} 1 & \cos\omega_1 & h'/a \\ \cos\gamma & \cos\omega_2 & k/b \\ \cos\beta & \cos\omega_3 & l/c \end{vmatrix} - \cos\omega_1(1-\cos\phi)\, D^{-1}\begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a \\ \cos\gamma & 1 & \cos\alpha & k/b \\ \cos\beta & \cos\alpha & 1 & l/c \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0 \end{vmatrix};$$

with similar expressions for k'/b and l'/c.

The formulæ of transformation for the case in which the angle of rotation is 180° can be found as follows :—

Since the point N is the middle point of PP', its projection on each axis is midway between the projections of P and P' on the same axis :—

$$\therefore\ OP\cos\theta_i+OP'\cos\theta_i'=2\,ON\cos\omega_i;$$

$$\therefore\qquad \cos\theta_i+\cos\theta_i'=2\cos\omega_i\cos PON.$$

Let as before the plane

$$hx/a+ky/b+lz/c=1$$

become $h'x/a+k'y/b+l'z/c=1$.

Then we must put $\cos\theta_1=\rho h/a$, &c. ; $\cos\theta_1'=\rho h'/a$, &c.

Hence
$$\frac{h+h'}{a\cos\omega_1}=\frac{k+k'}{b\cos\omega_2}=\frac{l+l'}{c\cos\omega_3}=2\,\frac{\cos PON}{\rho};$$

where $\dfrac{\cos PON}{\rho}$ is given by equation (8) of page 347, Vol. XII.

Note on a British Occurrence of Mirabilite.

By C. O. Trechmann, Ph.D., F.G.S.

[Read January 22nd, 1901.]

In August, 1900, several specimens of this mineral were found attached to gypsum-rock supplied to me from the quarry at Kirkby Thore, in Westmoreland, by Messrs. Joseph Robinson & Co., Ld., of Carlisle, who kindly inform me that the bed of this rock is about 20 feet thick, being overlaid by about 22 feet of marl, &c. There is very little anhydrite, not more than 2 or 3 inches, which, as a rule, is found in the middle of the bed of gypsum. Although I have used this rock for commercial purposes for years past in regular quantities, yet the mirabilite was never previously noticed.

The best specimen consisted of a layer, of about $\frac{5}{8}$ inch in thickness and about 2 inches long and broad, of perfectly clear, pellucid and colourless mirabilite, attached to the parent rock, a moderately coarse grained, dark grey gypsum; the specimen probably represented a portion of a lenticular cavity, originally completely occupied by the mirabilite, as the surface of the rock where the mirabilite rested exhibited minute clear crystals of gypsum. The mirabilite was of irregular form, having been partially dissolved here and there, and the exposed surface was more or less changed, by loss of water, to a white powder. On fracturing the salt, however, it was found, as already stated, to be perfectly limpid and colourless, with marked conchoidal fracture, and exhibiting on some of the fragments a perfect cleavage in one direction.

The following results were obtained, on analysis of clear unaltered fragments, by my assistant, Mr. G. P. Best. The water was estimated by careful heating up to 110°C in a platinum crucible, the residual salt dissolved in water acidulated with hydrochloric acid and the sulphuric anhydride precipitated as barium sulphate; the filtrate was treated with ammonium carbonate and the barium thus removed, and finally the sodium determined as chloride. Other constituents could not be detected.

			Percentage composition.	Calculated for $Na_2SO_4+10H_2O$.
Salt taken for analysis ..	·8800 gram.			
H_2O found ..	·4865 = ·4865	„ H_2O	= 55·28	55·90
$BaSO_4$ „ ..	·6450 = ·2657	„ SO_4	= 30·19	29·81
NaCl „ ..	·3100 = ·1219	„ Na	= 13·85	14·29
	·8741	„	99·32	100·00

The mirabilite is therefore a very pure Glauber Salt. Crystal faces were not observed, a fact easily understood when the great solubility and liability to efflorescence of this salt, and the peculiar natural conditions necessary for its preservation, are considered; and which would lead to the supposition that crystalline gypsum-rock is singularly impervious to percolating waters.

The only previous mention of mirabilite as a British mineral appears to be by D. C. Glen and John Young, Junr.[1] in a "List of Minerals and Rock Specimens found in the Central, Southern, and Western Districts of Scotland"; but the only information they give is "Mirabilite. Hurlet."

[1] Catalogue of Western Scottish Fossils. By J. Armstrong and others (Brit. Assoc. Adv. Sci.), Glasgow, 1876, p. 160.

Preliminary Note on an Improved Form of Three-Circle Goniometer.

By G. F. Herbert Smith, M.A.,

Assistant in the Mineral Department of the British Museum.

[Read November 13th, 1900.]

IN a previous paper[1] the author pointed out the advantages of a three-circle form of goniometer in the determination of the morphological characters of crystals; the crystal is adjusted once for all, and measurements may be made in any desired zone. A description was added of such an instrument, which had resulted from the addition of a two-circle apparatus to an ordinary Fuess goniometer with a single horizontal circle. This instrument has been in almost daily use since the end of June, 1899, and the author is, therefore, in a position to appreciate the ease and celerity with which crystals, however small, may be in this manner measured. As was remarked in the paper quoted above,[2] the adapted instrument has the disadvantage that measurements can only be made through little more than a right angle from the pole in which the zone to be measured and the zone of reference intersect, and, therefore, only half a zone can be measured without readjustment of the circles B and C.[3] To complete the zone, it is necessary to rotate C through a half-turn and to turn B till the axis of C makes the same angle with the vertical as before, but on the other side of it. If the crystal is morphologically perfect and the faces at the intersections of the two zones are present and give good reflections, the necessity for readjustment causes merely a little inconvenience; but, since crystals are seldom so complete and the particular faces may not be present, it will not be possible to obtain by direct measurement the angle between two faces which do not make angles of less than a right angle with the same pole of intersection of the zones,

[1] This Magazine, 1899, XII, 175-182; a translation appeared in Zeits. Kryst. Min. 1900, XXXII, 209-216.

[2] Ibid. footnote on p. 179.

[3] The same notation is employed here as before: A is the horizontal circle whose axis is fixed in space, B the vertical circle whose axis lies in a horizontal plane, and C the third circle.

and further it will not be possible in general to determine by observation whether three faces lie in the same zone.

The author has now devised a way of overcoming this difficulty by means of a change in the optical arrangements. Since the crystal is supported from underneath, we require the possibility of measuring through 180° from a pole in the zone of reference over the upper half of the crystal to the diametrically opposite pole ; in other words, we must be able to obtain reflections from both the faces parallel to B without rotating C. To effect this, the telescope and collimator are combined into an autocollimating telescope,[1] the tube of which is bent through a right angle in the horizontal plane, so that on rotation round the axis of A the circle B and the crystal lie on opposite sides of the object glass, and thus a reflection can be obtained from the face nearest the circle B, as well as from the parallel face. The author hopes in a future paper to describe in detail an actual instrument of this kind.

[1] If preferred, the telescope and collimator may have separate tubes, but both must lie in a *vertical* plane and be turned through a right angle.

Sulpharsenites of Lead from the Binnenthal.[1]

PART II.—*Rathite.*

By R. H. SOLLY, M.A.

(With Plate III.)

[Read November 13th, 1900.]

RATHITE, $3PbS.2As_2S_3$.

Literature.

Baumhauer, 1896, Zeits. Kryst. Min. XXVI, 593-602. Crystallography. with Analysis by Bömer. (Abstract Min. Mag. XI, 225.)

Jackson, 1900, Min. Mag. XII, 287. Analyses.

Crystallography.

System: Rhombic. $a : b : c = 0{\cdot}4782 : 1 : 0{\cdot}5112$.

These ratios are calculated from $010 : 350 = 51°27'$ and $010 : 111 = 70°45'$ measured on crystal No. 1 (see p. 81). A new orientation has been chosen for the crystals, so that the well-developed prism zone is vertical, and the cleavage plane, (001) of Baumhauer, becomes (010) to correspond with the cleavage of jordanite. The parametral plane has also been changed, chiefly on account of the pyramid planes. The corresponding forms being:—

Baumhauer	100	010	001	403	095	20.27.0	20.27.15
Solly	100	001	010	110	011	101	111

The axial ratios $a : b : c = 0{\cdot}668099 : 1 : 1{\cdot}057891$, as given by Baumhauer, become on recalculation $a : b : c = 0{\cdot}4737 : 1 : 0{\cdot}5251$.

The crystallographic observations have been made on 25 crystals, obtained from the Lengenbach quarries, in the Binnenthal. The table on page 78 contains a list of 62 known forms, 37 of which have not been observed before.

The base (001) is very rare, and only present as a very narrow plane. The brachypinacoid (010) is always present. The macropinacoid (100)

[1] Part I, General Description and Chemical Analyses, with a Crystallographic account of Jordanite. Min. Mag. 1900, XII, 282-297.

is rare, though sometimes fairly well developed. The crystals are always elongated along the Z axis. In the prism-zone (320), (340), (120) and (380) are characteristically well developed planes. The brachydome (011) is often largely developed and finely striated parallel to the X axis. The macrodome (101) is sometimes largely developed and deeply furrowed parallel to its intersection with (111). The pyramid planes, though numerous on some crystals, are always small and brilliant.

LIST OF KNOWN FORMS.

Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.
a	100	..	$\frac{5}{2}r$	250	..	$\frac{5}{2}k$	083	..
b	010	001	$\frac{7}{3}r$	370	..	$\frac{7}{3}k$	073	045
c	001	..	$\frac{9}{4}r$	490	7.0.12	$\frac{9}{4}k$	095	..
h	101	..	$2r$	120	203	†$\frac{7}{4}k$	074	..
$\frac{80}{3}r$	3.80.9	..	$\frac{7}{4}r$	470	..	$\frac{5}{3}k$	053	0.11.10
$18r$	1.18.0	..	$\frac{5}{3}r$	350	405	$\frac{4}{3}k$	043	..
$11r$	1.11.0	..	$\frac{4}{3}r$	340	101	k	011	..
$10r$	1.10.0	..	r	110	403	$\frac{10}{11}k$	0.10.11	021
$9r$	190	107	$\frac{5}{7}s$	870	302	$\frac{5}{6}k$	056	..
$8r$	180	106	$\frac{3}{5}s$	320	201	$\frac{5}{8}k$	013	0.16.3
$\frac{22}{3}r$	3.22.0	2.0.11	$2s$	210	..	$\frac{11}{5}q$	3.11.3	..
$7r$	170	..	$3s$	310	401	$3q$	131	..
$\frac{20}{3}r$	3.20.0	105	$4s$	410	..	$\frac{5}{2}q$	252	..
$6r$	160	209	$\frac{8}{3}s$	920	601	$\frac{7}{3}q$	373	..
$\frac{17}{3}r$	3.17.0	8.0.35	$7s$	710	..	$\frac{5}{3}q$	353	..
$\frac{16}{3}r$	3.16.0	..	$8s$	810	..	p	111	..
$\frac{14}{3}r$	3.14.0	207	†$15k$	0.15.1	..	$3t$	313	..
$4r$	140	103	$7k$	071	..	$5t$	515	
$\frac{11}{3}r$	3.11.0	23.0.66	$5k$	051		$2p$	211	..
$\frac{10}{3}r$	3.10.0	205	$\frac{7}{2}k$	072		$2m$	122	..
$3r$	130	..	$3k$	031	..	$\frac{3}{2}w$	132	..
$\frac{8}{3}r$	380	102						

† Twin planes, not found as faces.

The colour is lead-grey, but sometimes steel-grey, due probably to the inclusion of minute crystals of iron pyrites. Sometimes beautifully tarnished like jordanite. Streak chocolate colour. Opaque. Very perfect cleavage parallel to (010)[1]; also a parting parallel to (100). Fracture conchoidal. Hardness 3. Specific gravity 5·412, also 5·421: Baumhauer found 5·32. It is sometimes intimately associated with sartorite. The only known locality is the bed of the Lengenbach, Binnenthal.

[1] See Min. Mag. Vol. XII, 286.

Five different *habits* have been observed :—

I. Small, very brilliant lead-grey crystals, highly modified, showing little or no twinning. Fig. 1, Plate III.

II. Stout crystals of typical rhombic habit; (010) (011) (101) and prism faces are largely developed. Colour lead-grey to steel-grey. The most characteristic features of this habit are the numerous twin lamellæ and the parting parallel to (100). Analysed by Jackson (*loc. cit.* No. 13). This habit resembles Baumhauer's crystals, I and VI? Figs. 2 and 3.

TABLE OF CALCULATED ANGLES.

Zone [010, 100].	010, 870 = 67°17½′	Zone [010, 101].
010, 3.80.0 = 4°29′	, 320 = 72 19	010, 3.11.3 = 37°59½′
, 1.18.0 = 6 37½	, 210 = 76 33	, 131 = 43 40
, 1.11.0 = 10 46	, 310 = 80 56½	, 252 = 48 53
, 1.10.0 = 11 49	, 410 = 83 11	, 373 = 50 49½
, 190 = 13 5	, 920 = 83 56	, 353 = 59 48
, 180 = 14 39	, 710 = 86 5½	, 111 = 70 45
, 3.22.0 = 15 55	, 810 = 86 35	, 313 = 83 21½
, 170 = 16 38	, 100 = 90 0	, 515 = 86 0
, 3.20.0 = 17 25	Zone [010 : 001].	, 101 = 90 0
, 160 = 19 13	010, 0.15.1 = 7 26	Zone [010, 102].
, 3.17.0 = 20 15½	, 071 = 15 37	010, 132 = 55 56
, 3.16.0 = 21 24½	, 051 = 21 22	, 122 = 65 44
, 3.14.0 = 24 8½	, 072 = 29 12	Zone [100, 011].
, 140 = 27 36	, 031 = 33 6½	100, 211 = 27 43
, 3.11.0 = 29 42	, 083 = 36 16	, 111 = 46 25
, 3.10.0 = 32 6	, 073 = 39 59	, 122 = 64 33
, 130 = 34 52½	, 095 = 47 23	, 011 = 90 0
, 380 = 38 6½	, 074 = 48 11	.. ..
, 250 = 39 54½	, 053 = 49 34	010, 211 = 77 47
, 370 = 41 52	, 043 = 56 20½	100, 101 = 43 5½
, 490 = 42 54	, 011 = 62 55½	001, 211 = 65 32
, 120 = 46 16½	, 0.10.11 = 65 4½	, 111 = 49 50
, 470 = 50 4½	, 056 = 66 55½	, 353 = 53 48½
, 350 = 51 27	, 013 = 80 20	, 122 = 36 29
, 340 = 57 29	, 001 = 90 0	, 373 = 58 1½
, 110 = 64 26½		, 252 = 59 1½
		, 132 = 43 4
		, 131 = 61 51
		, 3.11.3 = 65 8

III. Flat rhombic prisms, with narrow (010) and well developed brachydomes. Exhibiting twin lamellæ, but not so numerous or so well marked as in habit II. Analysed by Jackson (No. 11). Fig. 4.

IV. Large rough crystals with splendid (010) cleavage; *no twin lamellæ*; of a dark steel-grey colour; usually mistaken for dufrenoysite. Similar to crystals II and III of Baumhauer. Analysed by Jackson (No. 12).

V. Rounded prisms roughly terminated, with very numerous fine twin

lamellæ ; of a lead-grey colour sometimes beautifully tarnished. Similar to crystal IV of Baumhauer. Fig. 5.

Twin laws.

I. Twin plane (074).

This twinning is only indicated by numerous very fine twin lamellæ.

II. Twin plane (0.15.1).

This is rare as a juxtaposed twin (Fig. 3), but fairly common as shown by small blade shaped prisms grown on the prism of the principal crystal. Two twinned crystals, as shown in Fig. 2 and in Baumhauer's Fig. 2, have been observed forming a triplet. The planes (074) (0.15.1) are not developed on any of the crystals.

Baumhauer, in his description of rathite, discusses the following possible causes of the fine striæ.

(*a*) Are the layers due only to parallel growth ?

(*b*) Are the layers due to twin growth ?

(*c*) Are the layers due to alternate banding of two isomorphous substances ?

On account of the analysis obtained by Bömer, Baumhauer considered that the fine striæ are due to alternate banding of $PbAsS_3$ and $PbSbS_3$ in the proportion of five molecules of the former to one of the latter. Jackson, out of five analyses of different rathite crystals, only once found any antimony (0·43 per cent.), while Bömer made one analysis and found 4.53 per cent. of antimony. I think there can be no doubt that the true composition of rathite is expressed by the formula $3PbS.2As_2S_3$, and therefore the chemical composition has nothing to do with the fine striæ.

Are the layers then parallel growths or twin growths ? Parallel layers would require some impurity between each layer, but Jackson did not find any difference in the chemical composition between crystals showing the lamellar structure and those not showing it. Parallel layers, as a rule, are uneven in thickness, and pass through the whole crystal. Now, these layers are remarkable for their even thickness, and do not always spread through the whole crystal or exhibit a pseudo-cleavage parallel to the layers. In the juxtaposed twin, described on page 83, one crystal shows lamellar structure, while in the other it is absent.

I therefore consider that the fine striæ are caused by twin lamellæ parallel to (074).

Baumhauer points out the close crystallographic relation between rathite and dufrenoysite. I shall in my concluding paper on this group discuss the morphotropic relationship of the whole group.

There is a specimen of rathite labelled "arsenomelane" in the Museum of Practical Geology, London. The name "arsenomelane" was given by von Waltershausen, and he supplied material for the analyses of Uhrlaub and Nason: the results[1] of these analyses agree closely with the formula $3PbS.2As_2S_3$, and there can be little doubt that most of the "arsenomelane" found in 1855-7 was rathite.

Description of Specimens.

Habit I. Fig. 1, Plate III.

This habit was observed on eight small crystals. One very small crystal, Fig. 1, was especially good.

Thirty-seven forms were determined, viz.:—

a, *b*, $\frac{8}{3}0r$, 18*r*, 11*r*, 9*r*, $\frac{22}{3}r$, 6*r*, $\frac{14}{3}r$, 4*r*, $\frac{10}{3}r$, 3*r*, $\frac{8}{3}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, 2*r*, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, *r*, $\frac{3}{2}s$, 2*s*, 3*s*, 4*s*, 7*s*, $\frac{7}{3}k$, $\frac{5}{3}k$, *k*, $\frac{11}{3}q$, 3*q*, $\frac{5}{2}q$, $\frac{7}{3}q$, $\frac{5}{3}q$, *p*, 2*p*, 2*m*, $\frac{3}{2}w$.

	Calculated.		Measured.	
010, 3.80.0 =	4°29′	...	4°27′ to 4°31′	narrow plane
, 1.18.0 =	6 37½	...	6 35 to 6 40	,,
, 1.11.0 =	10 46	...	10 44 to 10 47	,,
, 190 =	13 5	...	13 2 to 13 5	,,
, 3.22.0 =	15 55	...	15 52 to 15 56	,,
, 160 =	19 13	...	19 11 to 19 14	,,
, 3.14.0 =	24 8½	...	24 6 to 24 8	,,
, 140 =	27 36	...	27 32 to 27 38	,,
, 3.10.0 =	32 6	...	32 3 to 32 9	,,
, 130 =	34 52½	...	34 52 to 34 53	,,
, 380 =	38 6½	...	38 6 and 38 7	fairly large plane
, 370 =	41 52	...	41 50 to 41 52	narrow plane
, 490 =	42 54	...	42 51 to 42 57	,,
, 120 =	46 16½	...	46 16 and 46 18	large plane
, 470 =	50 4½	...	50 2 to 50 7	narrow plane
, 350 =	51 27	...	51 27	fairly large plane
, 340 =	57 29	...	57 30 and 57 32	large plane
, 110 =	64 26½	...	64 23 to 64 28	narrow plane
, 320 =	72 19	...	72 19	very large plane
, 210 =	76 33	...	76 25 to 76 40	narrow plane
, 310 =	80 56½	...	80 54 to 80 58	,,

[1] Min. Mag. XII, pp. 283 and 287, Nos. 17-20.

	Calculated.		Measured.		
010, 410	=83 11	...	83 8	to 83 14	narrow plane
, 710	=86 5½	...	86	to 86 10	,,
, 100	=90 0	...	90		small plane
010, 073	=39 59	...	39 53		narrow plane
, 053	=49 34	...	49 30		,,
, 011	=62 55½	...	62 57		small plane
010, 3.11.3	=37 59½	...	37 58	to 38	
, 131	=43 40	...	43 38	to 43 40	
, 353	=59 48	...	59 48	to 59 50	
, 111	=70 45	...	70 44	to 70 46	
100, 111	=46 25	...	46 24	to 46 26	
, 122	=64 33	...	64 30	to 64 36	
, 011	=90 0	...	89 58	to 90 1	
320, 111	=40 48	...	40 47		
, 353	=41 3	...	41 2		
340, 111	=40 39½	...	40 41		
, 353	=36 37	...	36 38		
350, 111	=41 52½	...	41 53		
, 353	=36 11½	...	36 13		
120, 111	=43 26½	...	43 30		
, 353	=36 30	...	36 32		

The forms 211, 132, 373, 252, 131, 3.11.3, 122 were determined by the following zones:—

211 [100, 111] [131, $\bar{1}$20]. 131 [010, 111] [320, $\bar{3}$53].
132 [131, 001] [010, 122]. 3.11.3 [010, 111] [340, $\bar{1}$11].
373 [010, 111] [320, $\bar{1}$11]. 122 [100, 111] [340, 353].
252 [010, 111] [130, 122].

There are also other minute pyramid planes which give no distinct reflections.

Habit II. Figs. 2 and 3.

This habit was observed on nine crystals; (010) (011) and (101) are largely developed, (010) is bright and smooth, (011) dull and finely striated parallel to the X axis, (101) with small (111) (313) (515) are rounded and deeply furrowed parallel to their mutual intersections, (320) (340) and (380) are largely developed.

Thirty-one forms were determined, viz. :—

a, b, c, $\frac{8}{3}0r$, $9r$, $\frac{22}{3}r$. $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, $4r$, $\frac{10}{3}r$, $\frac{8}{3}r$, $2r$, $\frac{5}{3}r$, $\frac{4}{3}r$, $\frac{3}{2}s$, $3s$, $\frac{9}{2}s$, $7s$, $8s$, $7k$, $5k$, $\frac{7}{2}k$, $3k$, $\frac{8}{3}k$, $\frac{7}{3}k$, k, p, $3t$, $5t$, h.

	Calculated.		Measured.	
010, 3.16.0	$=21°24\frac{1}{2}'$	...	$21°22'$ to $21°25'$	narrow plane
, 920	$=83\ 56$	...	83 52 to 83 58	,,
, 810	$=86\ 35$	...	86 30 to 86 40	,,
, 071	$=15\ 37$	...	15 34 to 15 40	,,
, 051	$=21\ 22$	...	21 20 to 21 26	,,
, 072	$=29\ 12$	...	29 14	,,
, 031	$=33\ 6\frac{1}{2}$	...	33 3 to 33 10	,,
, 083	$=36\ 16$	...	36 12 to 36 18	,,
, 313	$=83\ 21\frac{1}{2}$	...	83 to 83 30	rounded plane
, 515	$=86\ 0$	...	85 to 86	,,
, 101	$=90\ 0$	...	90 about	

The crystals belonging to this habit are always characterised by numerous twin lamellæ, according to law I (twin plane (074)).

Calculated.		Measured.
$010,074=48°11'$	...	$47\frac{1}{2}°$ to $48\frac{1}{2}°$

This angle was determined under a microscope fitted with cross wires and graduated circle. The crystals break parallel to (100), on which surface the lamellæ are well seen.

Very often small blade-shaped prisms are grown in twinned position on the prism planes of the principal crystal, according to law II (twin plane (0.15.1)). Triplets were also observed, according to law II (Fig. 2).

	Calculated.		Measured.
$(010), (\overline{0}\overline{1}0)=Z\overline{Z}$	$=14°52'$	...	15°
$(\overline{0}\overline{1}0), (\overline{\overline{0}}\overline{1}0)=\overline{Z}\overline{\overline{Z}}$	$=29\ 44$	...	30

The above angles were determined under a microscope by means of cross wires and a graduated circle.

One twinned crystal (Fig. 3) requires special notice. It is a juxtaposed twin, according to law II, and exhibits on the fractured surface of one crystal numerous twin lamellæ, according to law I.

The prisms are both well developed with (340) very large. On one crystal (072) gives a good reflection, (083) poor, and (073) rounded. The zone [010, 101] is rounded and deeply furrowed.

	Calculated.		Measured.
$010, \overline{0}\overline{1}0$	$=14°52'$	...	$14°55'$
, 072	$=29\ 12$	...	29 14
$010, \overline{0}\overline{1}0$	$=14\ 52$	...	14 50

This crystal consists of a number of similar crystals not quite parallel, as is seen when measuring round the prism zone.

Habit III. Fig. 4.

This habit was observed on three crystals. (010) is a narrow plane, while (320), (340), (120) and (380) are well developed. The brachydomes are well developed, and give good reflections. The twin lamellæ are not nearly so numerous as in habit II, and the parting plane (100) is *absent*.

Forty forms were observed, viz. :—

a, b, h, $\frac{8}{3}\breve{O}r$, $18r$, $11r$, $10r$, $8r$, $\frac{22}{3}r$, $7r$, $\frac{20}{3}r$, $6r$, $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, $4r$, $\frac{11}{3}r$, $\frac{10}{3}r$, $3r$, $\frac{8}{3}r$, $\frac{5}{2}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, $2r$, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, r, $\frac{3}{2}s$, $2s$, $4s$, $7s$, $7k$, $3k$, $\frac{7}{3}k$, $\frac{9}{5}k$, $\frac{5}{3}k$, $\frac{4}{3}k$, k, $\frac{5}{6}k$.

	Calculated.		Measured.	
010, 1.10.0	= 11°49′	...	11°45′ to 11°50′	narrow plane
, 180	= 14 39	...	14 35 to 14 45	,,
, 170	= 16 38	...	16 35 to 16 45	,,
, 3.20.0	= 17 25	...	17 20 to 17 40	,,
, 3.17.0	= 20 15½	...	20 10 to 20 20	,,
, 3.11.0	= 29 42	...	29 40 to 29 45	,,
, 250	= 39 54½	...	39 50 to 40	,,
320, $\bar{3}20$	= 35 22	...	35 22	sharp image
, 340	= 14 50	...	14 50	,,
340, 350	= 6 2	..	6 2	,,
350, 120	= 5 10½	..	5 10	,,
010, 071	= 15 37	...	15 36	good image
, 031	= 33 6½	...	33 6	,,
, 073	= 39 59	...	39 58	,,
, 095	= 47 23	...	47 20 to 47 25	poor image
, 053	= 49 34	..	49 35	good image
, 043	= 56 20½	...	56 25	poor image
, 011	= 62 55½	...	62 55	fair image
, 056	= 66 55½	...	67	poor image

Habit IV.

This habit was observed on some large rough crystals given to me by Dr F. Grünling, of Munich. They resemble in form habit II, but exhibit no twin lamellæ. These crystals are of a dark steel-grey colour with splendid cleavage parallel to (010). On breaking up the crystals for analysis minute crystals were found lining some of the cavities. Some of

the planes in the prism and brachydome zones were bright and large enough to measure.

Seventeen forms were observed, viz. :—

b, $18r$, $\frac{2}{3}^{2}r$, $\frac{1}{3}^{6}r$, $\frac{1}{3}^{1}r$, $3r$, $\frac{5}{2}r$, $2r$, $\frac{5}{3}r$, $\frac{3}{2}s$, $2s$, $3s$, $5k$, $\frac{7}{2}k$, $3k$, $\frac{8}{3}k$, $\frac{7}{3}k$.

Habit V. Fig. 5.

This habit was observed on one crystal. The crystal is in a cavity in the dolomite. It is a rounded prism with no definite terminations, with well-marked numerous twin lamellæ on the prism faces ; only approximate measurements could be obtained, but they conform with twin law I. It is identical in appearance to crystal IV of Baumhauer. An untarnished prism of jordanite may easily be mistaken for a rathite of this habit.

Tinguaites from Elfdalen and Rupbachthal: Basalts from Madagascar and the Soudan.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read June 19th, 1900.]

(I). *Cancrinite-Ægirine-Tinguaite* ("*Sussexite*"), *from Elfdalen, Sweden.*

(II). *Riebeckite-Ægirine-Tinguaite, from the Rupbachthal, Nassau. Compared with similar rocks from Abyssinia and the Canary Islands.*

(III). *Melilite-Basalt from Amparafaravola, Madagascar.*

(IV). *Hornblende-Basalt and Limburgite, from Ahmed Aga, White Nile.*

I. *Cancrinite-Ægirine-Tinguaite* ("*Sussexite*"), *from Elfdalen, Sweden.*

IN connection with the investigation of ægirine-anorthoclase rocks from Abyssinia, belonging to the grorudite-tinguaite series,[1] an examination was made of specimens of the so-called green phonolite from Elfdalen, which in the British Museum collection accompanied the more ordinary brown and red porphyry from that locality. In the descriptions of the well-known porphyry quarries of Elfdalen, mention is made of this green variety as occurring only in boulders.[2] Törnebohm was the first to record the occurrence of these rocks *in situ*, and to describe their characters.[3] They were found in the form of dykes in the neighbourhood of Heden, near Särna, Dalarne, Sweden, and were interesting as containing cancrinite in clear, well-defined porphyritic crystals as undoubtedly a primary constituent.

The name *Cancrinite-Ægirine-Syenite* proposed by Törnebohm is a rather misleading one, since neither in structure nor in mode of occurrence can these rocks be rightly regarded as belonging to the syenite group.

[1] Min. Mag. 1900, XII, 255-73.

[2] Hjelm. K. Vetensk. Akad. Nya Handl. 1805, pp. 106-8.

[3] Geol. För. Förh. 1883, VI, 383, and Abst. in Neues Jahrb. f. Min. &c. 1883, (ii),—370-.

The object of the present note is therefore to point out what appears to be the true position of these rocks in rock-classification as members of the *Grorudite-Tinguaite* series of Brögger.

Most of the rocks are tinguaites, but some are examples from the basic end of the series to which Brögger would apply the name of "*Sussexite*."[1]

Specimens of these more basic varieties in the Museum collection are olive-green felsitic-looking rocks, showing to the naked eye small transparent prismatic phenocrysts of cancrinite, and numerous long black needles of ægirine.

Under the microscope, porphyritic crystals of cancrinite, rounded nepheline and prismatic ægirine are seen in a fine-grained groundmass, consisting of minute felspar needles and a dense mesh of ægirine needles, such as is characteristic of most grorudites. No felspar phenocrysts are present.

The long, deep grass-green phenocrysts in one specimen consist of true ægirine giving nearly straight extinction and compensating with the quartz-wedge along the length. In another specimen, however, somewhat paler green phenocrysts appear to be intermediate between ægirine and ægirine-augite, for the extinction in most sections varies from 10° to 18°, and compensation takes place along the length (a axis of indicatrix 18° from crystallographic axis *c*): some of the sections had darker green ragged terminations of true ægirine, giving nearly straight extinction.

A quantitative analysis of this rock gave the following result (I), as compared with that of nepheline-porphyry ("Sussexite") (II), from Beemerville, New Jersey, described by Kemp[2]:—

		I.		II.
SiO_2	...	48·83	...	45·18
Al_2O_3	...	18·71	...	23·31
Fe_2O_3	...	4·16	...	6·11
FeO	...	1·91	...	
CaO	...	5·19	...	4·62
MgO	...	1·02	...	1·45
Na_2O	...	10·63[3]	...	11·17
K_2O	...	3·04	...	5·95
Ign.(CO_2+H_2O)		5·52	...	1·14
		99·01		98·93

[1] Brögger. Eruptivgesteine des Kristianiagebietes, 1894, I, 173.

[2] Trans. New York Acad. Sci. 1892, XI, 60.

[3] Probably slightly under estimated.

In mineral composition and structure the rock is obviously closely related to members of the grorudite-tinguaite series, while the analysis shows that in chemical composition it approaches the basic end of the series, the type-rock of which is the so-called nepheline-porphyry of Kemp (" Sussexite " of Brögger) from Beemerville, New Jersey.

The chemical relationship of the Elfdalen rock to other members of the series is seen in the following table[1] :—

	Grorudite Varingskollen.	Grorudite Kallerud.	Sölvsbergite Longenthal.	Tinguaite Hedrum.	Sussexite Elfdalen.	Sussexite Beemerville.
SiO_2	74·35	71·35	62·70	56·58	48·83	45·18
Al_2O_3	8·73	12·21	16·40	19·89	18·71	23·31
Fe_2O_2(FeO)	7·21	6·76	5·99	4·34	6·07	6·11
CaO	0·45	0·22	0·95	1·10	5·19	4·62
MgO	0·07	—	0·79	0·13	1·02	1·45
Na_2O	4·51	6·51	7·13	10·72	10·63	11·17
K_2O	3·96	3·22	5·25	5·43	3·04	5·95
$H_2O(CO_2)$	0·25	0·33	0·70	1·77	5·52	1·14

II. *Riebeckite-Ægirine-Tinguaite, from the Rupbachthal, Nassau. Compared with similar rocks from Abyssinia and the Canary Islands.*

This rock has been described as a proterobase[2], and as a diorite-porphyrite.[3] In the present note it is referred to the tinguaite (phonolite) group, owing to the striking resemblance in characters which it presents with tinguaites from Abyssinia, described in the paper already referred to.[4]

Specimens of the rock in the British Museum collection are dark greenish black, and show only a few small phenocrysts of felspar. Under the microscope one or two long phenocrysts of orthoclase (or possibly anorthoclase), with straight extinction and showing no twin striations, are seen in a trachytic groundmass of felspar laths, scattered through which are ragged tufts and feathery patches of grass-green ægirine and riebeckite (with pleochroism from yellow to deep indigo-blue). The latter minerals are especially accumulated round patches of an altered mineral,

[1] See Brögger. Eruptivgesteine des Kristianiagebietes, 1894, I, 176.

[2] W. Schauf, Unters. nassauische Diabase. Inaug.-Diss. Bonn, 1880, p. 17.

[3] Zeits. Deutsch. geol. Ges. 1883, XXXV, 216.

[4] Min. Mag. 1900, XII, 268.

showing in one or two cases sharp hexagonal outlines. This structure is so very similar to that of the tinguaite from Amba Gollo, near Axum, Abyssinia (see Min. Mag. XII, Pl. III, fig. 5), that the altered mineral is here referred to nepheline. Besides ægirine and riebeckite there are moss-like patches of a nearly opaque mineral which in some parts show pleochroism from pale reddish brown to deep red nearly opaque. The same mineral occurs in small amount in the tinguaite from Abyssinia referred to above, and also in the paisanite described in the same paper. It is most probably the soda-amphibole *Cossyrite*.

Very similar to the Rupbach rock both macroscopically and microscopically are specimens in the Museum collection from Gran Canaria and Teneriffe.

Thus a dark greenish rock from the Guimar Road, Gran Canaria, shows in thin section under the microscope one or two long Carlsbad twins of orthoclase (or possibly anorthoclase, which is the prevailing felspar in many specimens of phonolite from the Canary Islands) in a trachytic groundmass of felspar laths with feathery tufts of ægirine and a hornblendic mineral, showing extinctions as high as 30° and pleochroism from pale yellow to purplish brown, and thus closely related to the *Catophorite* of Brögger: ragged patches of altered *Cossyrite* are also present. A specimen from Tiraxana, Gran Canaria, is similar, and shows also large irregular phenocrysts of altered nepheline surrounded by ægirine, as in the Rupbach rock.

Many of the phonolitic rocks of Cripple Creek, Colorado, described by Cross,[1] appear to be of a very similar character.

III. *Melilite-Basalt from Amparafaravola, Madagascar.*

The specimen of this rock in the Museum collection is from a collection of Madagascar rocks, presented in 1889 by the Rev. J. Wills.

It is a dark, fine-grained basalt, showing in section characters very similar to those of the well-known melilite-basalt of Hochbohl, Württemberg. Very numerous small phenocrysts of olivine occur in a base of pale purple augites, with small prismatic melilites and magnetite grains.

The melilite has a slightly brownish tint, but is clear and free from inclusions like the Hochbohl mineral: it occurs in lath-shaped crystals, often club-shaped at the ends, which give straight extinction and compensate with the quartz-wedge across their length like the Hochbohl melilite: the double refraction is very low to almost isotropic: no peg-structure was observed.

[1] XVI Ann. Rep. U. S. Geol. Survey, 1894-5, Part II, p. 35.

Purplish-brown, strongly refractive grains are doubtless to be referred to perofskite, the constant companion of melilite.

IV. *Limburgite and Hornblende-Basalt-Scoria from Ahmed Aga, White Nile.*

Ahmed Aga is an isolated hill in the desert country, about 100 miles north of Fashoda, on the White Nile. The specimens here described, which were collected and presented in 1900 to the Museum by Capt. Stanley Flower, show that the hill is of volcanic origin. They consist of basalt-scoria, compact limburgite and large fragments (up to 1 in. square) of basaltic hornblende.

The limburgite or magma-basalt is a dense black rock, showing a few small phenocrysts of olivine. Under the microscope small irregular and rounded phenocrysts of olivine, and a few phenocrysts of a pale purple augite, with colourless centres, are seen in a dense groundmass, made up mainly of pale purple augite microlites, with some olivine and magnetite grains, in a nearly colourless isotropic base. One or two foreign fragments of quartz are present, surrounded by the usual alteration-zone of pale-green augite needles. Many of the olivine phenocrysts have suffered partial absorption, and are surrounded by a broad margin of granular augite.

The basalt-scoria shows in thin section irregular phenocrysts of a pale-green augite, altered olivine, and deep red basaltic hornblende, with one or two small fragments of felspar (showing no twin-striations) in a dense, nearly opaque, glassy base.

OBITUARIES.

Charles Friedel, although most distinguished as a chemist, had a considerable reputation as a Mineralogist and Crystallographer. He was born at Strassburg on March 12th, 1832, and graduated in mathematics and physics at the University of Paris with special honours. His first public appointment (1856) was that of Curator of the Mineralogical Collection of the Paris School of Mines. In 1876 he became Professor of Mineralogy in the University, and eight years later succeeded Professor Wurtz in the Chair of Organic Chemistry. He received the distinguished honour of membership of the Institute (Academy of Sciences) in 1878, and in 1881 was President of the French Mineralogical Society. His numerous mineralogical papers deal with the pyroelectrical phenomena of crystals, the artificial production of minerals, and other subjects of a miscellaneous and descriptive character. The minerals adamite, wurtzite, delafossite and (in conjunction with another author) carnotite were first described by him; the mineral friedelite perpetuates his name.

Friedel's death took place on April 20th, 1899. A detailed account of his mineralogical work, together with an excellent portrait, is given by P. Curie in *Bull. Soc. franç. Min.* 1900, XXIII, 171-190.

Peter Waage, an original honorary member of the Society, died in January 1900, in his 67th year. Since 1862 he had held the post of Professor of Chemistry in the University of Christiania. As a chemist he was interested in the analysis of minerals, and he was also joint author of a primer of crystallography.

Townshend Monckton Hall, an original member of the Society, and a contributor to the Magazine, died July 1st, 1899, at the age of 54. He was well known as a local authority on the geology and mineralogy of Devonshire, and was the author of a very useful topographical index to British mineralogy, "The Mineralogist's Directory," published in 1868.

REVIEWS.

Elements of Mineralogy, Crystallography and Blowpipe Analysis from a practical standpoint. By A. J. Moses, Professor of Mineralogy, Columbia University, and C. L. Parsons, Professor of General and Analytical

Chemistry, New Hampshire College. New enlarged Edition. Pp. vii + 414. 664 Figures. (New York: D. Van Nostrand Company, 1900. Price $2.00 net.)

This is one of the best text-books that can be recommended to students of elementary mineralogy. Clear and concise statements in short paragraphs are admirably arranged under prominent head-lines, so that the text is easy to read and convenient for reference. On many pages there are eight different kinds of type. The book is full of excellent illustrations of an original character; those from photographs of actual specimens are, as a rule, good, but others, as might be expected, do not show very much, and would have been better omitted.

Part I, dealing with crystallography, describes the more important of the 32 classes of crystals; there are also short chapters on the measurement and drawing of crystals, but no mention is made of stereographic projection. Part II gives an excellent account of the methods of blow-pipe analysis. The third part, headed descriptive mineralogy, includes five chapters on the optical and other characters of minerals, and these might very well have formed a part by themselves. The chapters on optical characters will be useful to beginners in microscopic petrography.

This edition differs considerably from the first edition of 1895; there are 328 more figures, the crystallography and determination tables have been re-written, and the remainder extensively revised.

A Text-book of Important Minerals and Rocks, with Tables for the Determination of Minerals. By S. E. Tillman, Professor of Chemistry, Mineralogy and Geology, U.S. Military Academy, West Point, N.Y. Pp. viii + 176. 38 Figures. (New York: John Wiley & Sons. London: Chapman & Hall, 1900. Price $2.00 net.)

This book is quite elementary, and, in fact, almost popular in character. The most unsatisfactory part is that dealing with crystallography, which is very sketchy and contains many incorrect statements, while head-lines like the following only lead to confusion:—"*Crystallographic Law—Law of Axial Ratios, or Rationality of Parmeters* [*sic*] *or Indices.*" The part giving descriptions of 75 common minerals is better, but here the arrangement of the main headings requires considerable revision: for example, native copper and cinnabar come, without any break in the text, under ores of silver. Tables for the determination of the 75 species are unduly long, occupying no less than 40 pages. The concluding part gives a short account of rocks on the lines adopted in elementary text-books of geology.

ABSTRACTS.

Minerals of Ceylon. A recent number of Groth's *Zeitschrift* (Band XXXIII, Heft 3-5, 1900) contains a series of important papers resulting from Dr. F. Grünling's mineralogical expedition to Ceylon in 1896-7. Dr. Grünling himself gives a general account (pp. 209-239) of the geology and mineralogy of the island, and of the industries connected with pearl fishing, graphite mining, and the washing of gem-gravels. An excellent map gives the positions of the mineral localities: these are almost all situated in the south-central portion of the island. The crystalline rocks (granulites) contain veins of graphite, and beds of limestone and dolomite, in which are various crystallised minerals. The precious stones, the principal localities for which are Ratnapura and Rakwana, are extracted from the gravels of existing and of ancient streams; they include sapphire, less frequently ruby, chrysoberyl, spinel (often of a fine blue colour), zircon, tourmaline, rutile, garnet, several varieties of quartz, &c. The corundum and spinel appear to have been derived from the crystalline limestones.

This paper includes a description, with several analyses, by E. C. Schiffer (also in Inaugural-Dissertation, München, 1900, pp. 32-45) of a coarsely crystalline dolomite, from Wattegama, near Kandy, and of the minerals enclosed in it, namely, blue apatite, phlogopite, hydrophlogopite, serpentine, pyrites, pyrrhotite, and spinel.

A paper (pp. 263-454), by V. von Worobieff, gives a detailed crystallographic description of the tourmaline crystals collected by Dr. Grünling (supplemented by other material); this is illustrated by seven plates, with 99 figures. With few exceptions these crystals are brown in colour, and vary in habit from lenticular to prismatic; they are brilliant and very rich in forms, there being as many as 59 on one crystal. A long list of crystal forms includes no less than 131 which have not been observed before, and a table of measured and calculated angles extends over 43 pages. The rhombohedral angle rr' is determined as 47°13′39″ (mean of 48 angles on 15 crystals, with the limits 47°5½′ to 47°19′); this corresponds with $a : c = 1 : 0{\cdot}45181$. No definite connection could be traced between the development of the faces and the pyroelectrical character of the two ends of the crystals, and there are many exceptions to Rose's rule as quoted in the text-books. The antilogous pole, how-

ever, shows many unusual forms, and the faces are further distinguished by striations and irregularities of growth ; except in the case of crystals showing complex combinations, the two poles can only be distinguished by a pyroelectrical examination. The symmetry of tourmaline, as shown by the development of the faces and the etch-figures, is ditrigonal-pyramidal (acleistous-ditrigonal class of Lewis), and not hemimorphic-tetartohedral (acleistous-trigonal of Lewis) as has been suggested by a few authors.

G. Melczer (pp. 240-262) gives crystallographic and optical determinations of the chrysoberyl, sillimanite and blue spinel. Sillimanite is represented by a single prismatic crystal, which is transparent and pale-blue, with peculiar pleochroism.

The same number of the *Zeitschrift* also contains a description by V. Goldschmidt and H. Preiswerk (pp. 455-467) of a twin-crystal of chrysoberyl, brought from Ceylon by Prof. C. Schmidt. From their own and from Melczer's measurements these authors deduce the most probable values of the axial ratios of chrysoberyl as $a : b : c = 0{\cdot}4708 : 1 : 0{\cdot}5823$.

Mention may here be made of a recent paper " On Ceylon Rocks and Graphite," by A. K. Coomára-Swámy (*Quart. Journ. Geol. Soc.* 1900, LVI, 590-615). This is mainly a description of the crystalline rocks and the mode of occurrence of graphite. Chemical analyses are given of some rock-forming minerals ; and minerals from the gem-gravels are briefly described, with a list of observed crystalline forms in the case of corundum. L. J. S.

Minerals from South Greenland. (G. Flink, O.B.Boeggild and C. Winther, *Meddelelser om Grönland*, 1900, XXIV, 1-213, 9 Plates).—This long paper, which is written in English, describes in detail the large amount of material collected by Dr. Flink in the summer of 1897 in the nepheline-syenite district of Julianehaab. The first part (pp. 7-180) by Flink deals with 34 mineral species collected from a coarse gravel, which has resulted by the weathering *in situ* of pegmatite masses in the syenite, on the plateau of Narsarsuk. Nine new species were determined, namely, ancylite, chalcolamprite, cordylite, endeiolite, leucosphenite, lorenzenite, narsarsukite, spodiophyllite, tainiolite, and a new variety of apatite—yttrium-apatite. A summary of the characters of these has already been given in this Magazine (vol. XII, p. 378). Among other crystallised minerals may be mentioned ægirite, arfvedsonite, catapleiite, elpidite, epididymite, eudidymite, eudialyte, neptunite and parisite.

The second part (pp. 181-213), by Boeggild and Winther, gives the characters of the new minerals epistolite, britholite and schizolite (see Min. Mag. XII, p. 378), and also of steenstrupite. L. J. S.

Chemical Composition of Sulphohalite. (S. L. Penfield, *Amer. J. Sci.* 1900, [iv], IX, 425-428, and *Zeits. Kryst. Min.* 1900, XXXIII, 523).—From the single partial analysis which has previously been made of sulphohalite the formula was deduced as $3Na_2SO_4.2NaCl$. Recent attempts by de Schulten and by van't Hoff and Saunders to prepare this compound artificially have failed, and the existence of sulphohalite has consequently been doubted. A new analysis of the mineral was therefore desirable. This was performed on a portion of the original crystallised material, and the results give the new formula $2Na_2SO_4.NaCl.NaF$. The presence of fluorine is unexpected, but may be explained by the borax deposits of Borax Lake, San Bernardino Co., California, having been formed by fumarole action. Intimately associated with sulphohalite is hanksite ($9Na_2SO_4.2Na_2CO_3.KCl$), a mineral also containing three acid radicles. L. J. S.

Chemical Composition of Turquoise. (S. L. Penfield, *Amer. J. Sci.* 1900, [iv], X, 346-350, and *Zeits. Kryst. Min.* 1900, XXXIII, 542).—The formula of turquoise is usually given as $2Al_2O_3.P_2O_5.5H_2O$, the copper, which is always present, being considered to be an accidental impurity to which the colour of the mineral is due. In order to establish a formula a new analysis has been made on carefully selected material from the Crescent Mining district, Lincoln Co., Nevada. This is of a fine robin's-egg blue colour, and breaks with a smooth fracture; under the microscope it appears to be homogeneous, and there is no evidence of the presence of two substances. The results of the analysis are :—

P_2O_5.	Al_2O_3.	Fe_2O_3	CuO.	H_2O.	Insol.	Total.	Sp. gr.
34·18	35·03	1·44	8·57	19·38	0·93	99·53	2·791

A consideration of this and other reliable analyses suggests that the copper is present as an essential constituent of the mineral, and this is also supported by the fact that finely-powdered turquoise dissolves in hydrochloric acid as a whole without discolouration. The new formula, $[Al(OH)_2,Fe(OH)_2,Cu(OH),H]_3PO_4$, represents the mineral as a derivative of ortho-phosphoric acid, with the hydrogen atoms largely replaced by the univalent radicles $Al(OH)_2$, &c. In some analyses approximately two-thirds of the hydrogen atoms are so replaced, and the formula becomes $[Al(OH)_2, Fe(OH)_2, Cu(OH)]_2HPO_4$. L. J. S.

Chemical Composition of Tourmaline. Two more papers have recently been contributed to the discussion now taking place concerning the composition of tourmaline. (See Abstract, *Min. Mag.* XII, 216, 309.)

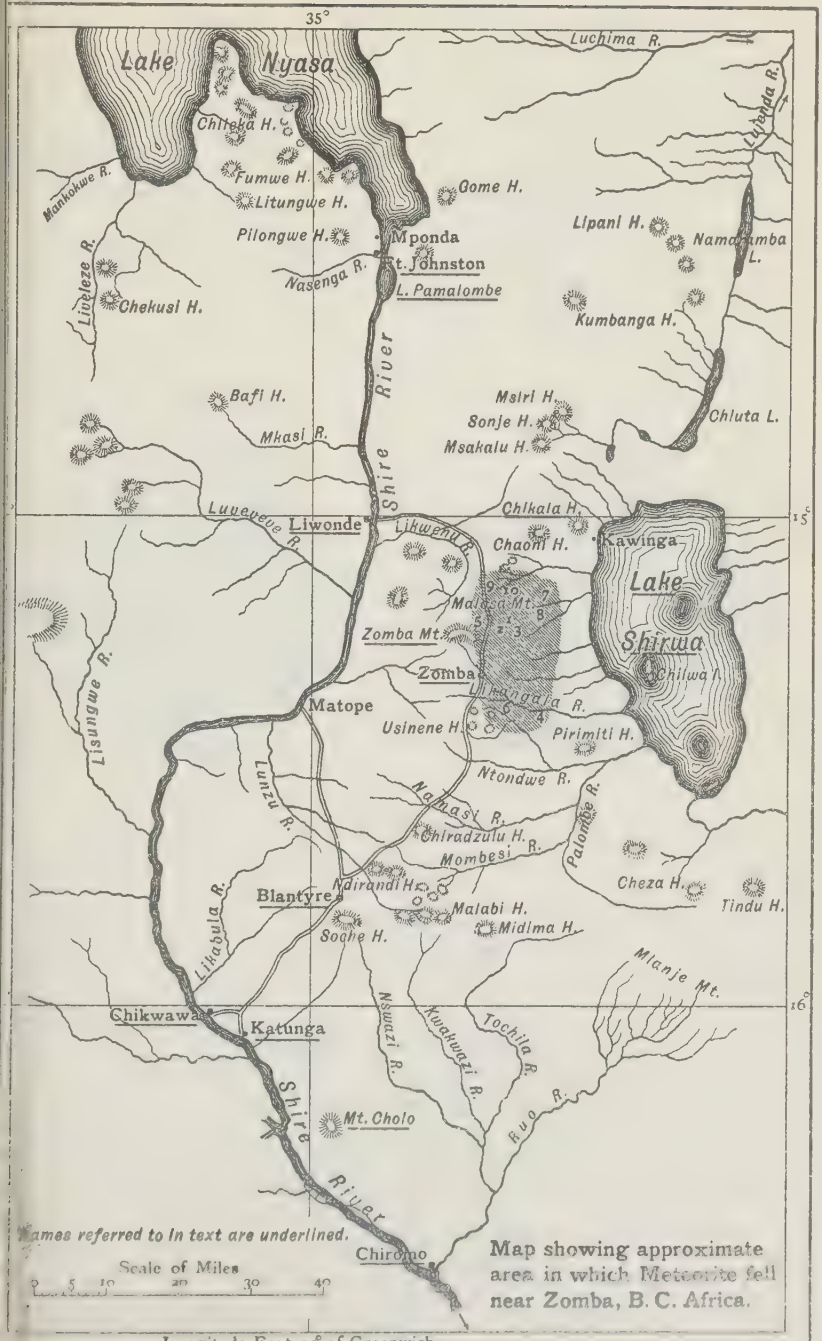
S. L. Penfield replies (*Amer. J. Sci.* 1900, X, 19-32; and *Zeits. Kryst. Min.* 1900, XXXIII, 527) to the various criticisms of his formula, and makes some interesting general remarks as to the reliability of mineral analyses.

E. A. Wülfing (*Programm z.* 82 *Jahresfeier d. k. Württemb. landwirt. Akad. Hohenheim*, 1900, 99 pp.) discusses the connection between the crystallographic constants and the chemical composition, and represents in a coloured diagram the results of the 33 best tourmaline analyses. Previously published constants are discussed, and numerous new crystallographic, optical and density determinations are given of material which was, whenever possible, the same as that analysed by previous authors. For crystals from various localities the angle rr' varies from 46°48′ to 47°15′, the corresponding values of the c axis being 0·4469 and 0·4521 respectively. The refractive indices and double refraction also vary considerably: $\epsilon = 1{\cdot}6159$ to $1{\cdot}6572$; $\omega = 1{\cdot}6354$ to $1{\cdot}6918$ (for line H). Sp. gr. 3·007 to 3·240. The double refraction and the sp. gr. both increase with the amount of iron. Four groups of tourmaline may be distinguished, namely, those rich in (1) lithium, (2) ferrous iron, (3) ferric iron, and (4) magnesium. The iron tourmalines are black, but those of the second group have pale reddish-violet and blue as axial pleochroism colours, while those of the third group have brownish and dark-green.

New analyses of tourmaline are given by H. Beermann (*Inaug.-Diss. Erlangen*, 1899; Abstract in *Neues Jahrb. Min.* 1900, II, Ref. 26).

L. J. S.

Diamond Field of the Great Lakes. (W. H. Hobbs, *Journal of Geology*, 1899, VII, 375-388.)—Since 1883 seventeen diamonds, varying in weight from ½ to 21¼ carats, have been found in glacial deposits in the region of the great lakes of North America, principally in the State of Wisconsin. The predominating crystal forms are the rhombic dodecahedron and a hexakis-octahedron; the stones are colourless or tinted with green or yellow. By plotting the diamond localities and directions of the glacial striæ on a map it is seen that the diamonds probably came from somewhere near James Bay on Hudson Bay, though a more detailed study of the glacial geology of the region will be needed before the home of the diamond can be exactly located. L. J. S.



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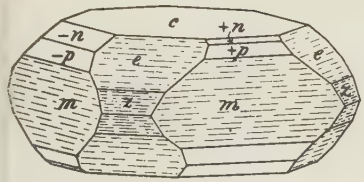
L. FLETCHER: ZOMBA METEORITE.



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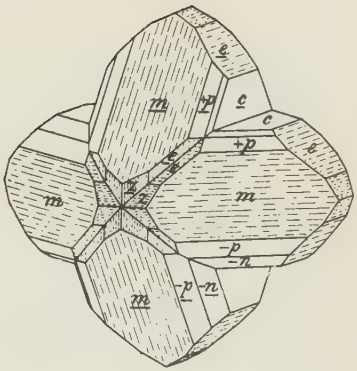

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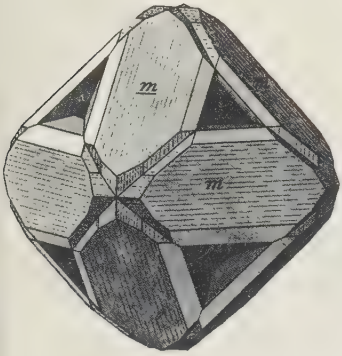

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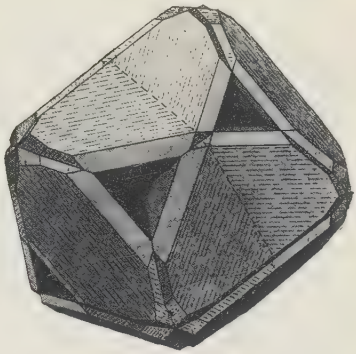

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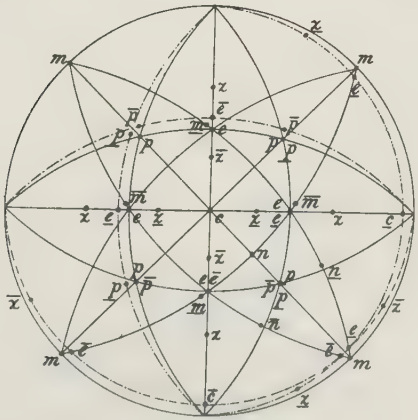

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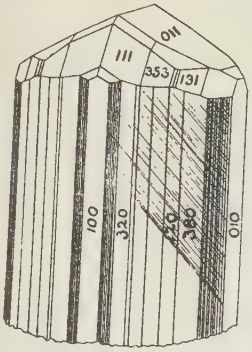
L. J. SPENCER: STANNITE FROM BOLIVIA.



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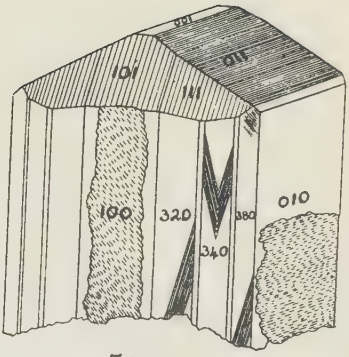

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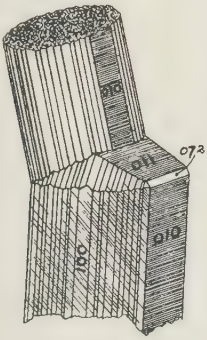

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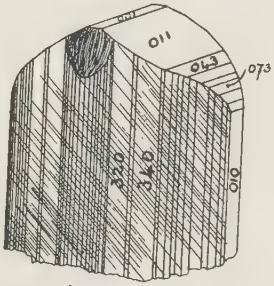

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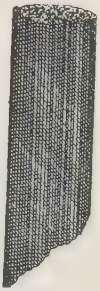

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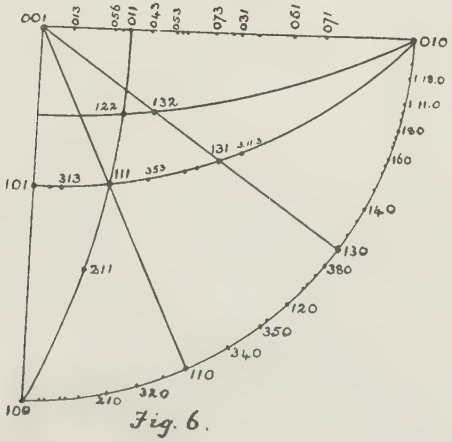

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